Arterial Variations in Humans: Key Reference for Radiologists and Surgeons

Classification and Frequency

1st Edition

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Contents

Foreword

Arterial Variations in Humans: Key Reference for Radiologists and Surgeons is based on the landmark work *Arterial Variations in Man: Classification and Frequency* by Lippert and Pabst, first published in 1985. With the collaboration of German radiologist Frank Wacker and his team, the original atlas has now been expanded. The schematic drawings have been enhanced with angiograms from digital subtraction angiography, computed tomography, and magnetic resonance imaging.

The beauty and diversity of the human body is one of the first things medical students learn, and the complexity is something that both students and experts appreciate greatly. Although detailed anatomic knowledge is a cornerstone of medical education, the wide range of basic facts and more advanced scientific findings that accumulate over the course of a doctor's medical life increase the likelihood that only "normal" textbook anatomy remains in focus at later stages of a medical career. However, not infrequently, basic anatomic, surgical, and radiologic textbook knowledge does not meet the needs of addressing the complex reality of an individual patient's anatomy, creating significant challenges for medical professionals. In imaging, such anatomic findings should be recognized and reported in a manner similar to pathologic changes. In surgery and interventional radiology, variants must be accurately recognized to avoid patient harm if they are not correctly addressed during a procedure.

Therefore, a comprehensive and illustrative summary of arterial variants beyond the "normal" anatomy described in textbooks helps not only radiologists in describing such variants, but also interventional radiologists, surgeons, and others who rely on arterial access. The exquisite combination of angiograms and schematic drawings in this book is an invaluable resource to understand and visually memorize patterns we might encounter during our daily work.

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Preface

During my angiography and interventional radiology rotation as a radiology resident I was fascinated by the delicate arteries one could see when contrast medium was injected into them. At the same time, I was often disappointed that many arteries did not follow the course given in standard anatomy textbooks. The remarkable diversity of arterial anatomy sometimes made me feel lost for words when it came to the reports we had to write after the procedure. At that time, there was a small reference library in our radiology department and I was quite grateful that it included a thin book by Lippert and Pabst, published in 1985 and entitled *Arterial Variations in Man: Classification and Frequency*, which helped me to understand the complexity of arterial anatomy. The sketches in this book nicely delineated a multitude of variants in many arterial territories. The bundled information on the frequency of arterial anomalies, often hidden in old and inaccessible journals and books, was an important asset for my studies. Not only radiology residents but also many of our colleagues from the surgical field cherished this book. Variations in the arteries supplying a given organ are usually harmless; however, the correct detection and interpretation of pathologic changes requires knowledge of both the normal and the anomalous arterial blood supply. In addition, under certain circumstances some variants can have a negative effect. This is especially relevant for therapy planning in surgery, endoscopy, and interventional radiology, where an intimate knowledge and an understanding of the blood supply prior to a procedure helps to avoid unpleasant surprises during intervention.

Many years after my first contact with Lippert and Pabst's book, I became Chairman of Radiology at Hannover Medical School in Germany, the alma mater of Professors Lippert and Pabst, and I got to know them in person. I expressed my appreciation for their book and we discussed the substantial advances that had been made in both invasive and noninvasive vascular imaging since its publication. In digital subtraction angiography (DSA), improved tubes and detectors offer high-spatial-resolution angiography. In computed tomography (CT), data sets with submillimeter voxel size in combination with postprocessing tools such as multiplanar reconstruction, maximum intensity projection, and volume rendering have become clinical standard. In magnetic resonance imaging (MRI), higher field strengths and fast imaging techniques offer excellent spatial and temporal resolution. These technical improvements offer an excellent delineation of the vascular anatomy with almost every DSA scan and with many CT and MRI recordings. We all agreed that, owing to the more detailed visualization of the arteries on routine imaging, familiarity with both normal anatomy and its variants is becoming more important. Based on these interdisciplinary discussions between a radiologist and two anatomists, the idea was born to publish a new atlas.

We decided to keep the schematic drawings of the arteries from the original book. The artists at Thieme redrew the schematics and added some color for a crisper layout. We added radiologic images for the more common variants visible with CT, MRI, and DSA. Given the small frequencies of some of the variants, we were not able to provide radiologic images for every schematic drawing.

We are greatly indebted to many colleagues and coauthors at Hannover Medical School who contributed to our project. We also received some sample images, even images for entire chapters, from colleagues at other institutions. The support of our colleagues and friends who supplied images is greatly appreciated. We would also like to thank Martina Habeck for editorial support and all the staff at Thieme for their help and patience.

We would be delighted if colleagues and readers of this atlas would send us additional CTA, MRA, or DSA images of variants. In addition, we would appreciate any information on recent or upcoming papers on arterial variations, and we will be more than happy to start a discussion on frequencies as well as on the relevance of certain findings in this field.

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Abbreviations

3D	three-dimensional
AvIP	average intensity projection
CT	computed tomography
CTA	computed tomography angiography
DSA	digital subtraction angiography
MIP	maximum intensity projection
MRA	magnetic resonance angiography
MRI	magnetic resonance imaging
VR	volume-rendered

1 Introduction

Textbooks on anatomy, radiology, and surgery usually describe only the “normal” arterial blood supply. However, for some arteries this “normality” is found in less than 30% of all patients, whereas for other arteries it is found in over 95% of patients. Rarely mentioned are deviations in an artery’s origin, its topographical localization, or the area it supplies. Such deviations can be classified into two groups: malformations and variations. Malformations often have a negative influence on the function of the given organ under normal circumstances—for example, this is the case if both coronary arteries originate from the pulmonary artery. In the current book, this group will be dealt with in only a few instances. Variations, by contrast, generally have no effect on the function of the organ under normal circumstances—for example, a superficial brachial artery does not have a negative effect on the function of the forearm and hand. However, should the superficial artery be mistaken for a vein and should a thiobarbiturate be injected, severe necrosis of the hand would result. Thus, even a harmless variation can have negative effects under certain circumstances.

The basis for the current book is a surge of clinical interest in the topographical anatomy of the arterial blood supply, the origin of arteries, and the areas supplied by individual vessels. Every day, superselective angiography and angiographic interventions are performed on many organs in many angiography labs. Given the striking improvements in imaging technology, it has now become possible to visualize in vivo smaller arteries and branches that could formerly only be identified in carefully dissected anatomical preparations. Modern surgical techniques depend on the intimate knowledge of both the “normal” and the anomalous arterial blood supply. For instance, when selective transarterial chemoembolization or radioembolization is used for the treatment of hepatic cancer, even small aberrant hepatic arteries can cause significant side effects due to off-target embolization. Microsurgical techniques employed in vascularized transplants and repairs after trauma also depend on the sound knowledge of arterial variations.

Many terms are found in the literature to describe the variations of arteries, such as *aberrant, replaced, supplementary,* or *accessory* arteries. We have used the term *replaced artery* to refer to a single artery that supplies an organ in place of the artery that normally supplies it. An *accessory artery* is a second artery in addition to the one normally present, without any specification of size. There is no general agreement on whether minute vessels with very small diameters and hardly any significant blood flow should also be considered.

The determination of the frequency of arterial variations poses some obvious problems, especially when combining anatomic dissections and angiographic techniques ex vivo and in vivo. First, there is a broad spectrum of techniques between radiology, anatomy, and pathology labs that might show different aspects of the vasculature. Second, patient selection bias might be present. In radiology, the patients examined with CT or MRI are usually sick, and in many instances the examination is targeted toward an organ with pathology. Smaller variant arteries might be missed owing to limited spatial resolution or simply overlooked because they were not expected. In certain diseases, small branches increase in size, making it difficult to define whether they are variants of the normal blood supply or represent a pathologic condition. Invasive angiographic data are never based on a representative group of patients because there was of course an indication for the angiography. Although selection bias is also present in pathology when the cause of a patient’s death is determined, unaffected organs can also be examined. In anatomy, many dissected corpses are from rather old patients with some kind of pathology, which also introduces selection bias.

The frequencies of variant arteries can be underestimated because small accessory vessels may be missed or cut, and not all arteries are filled in corrosion cast preparations. Therefore, different observations and different frequencies of anatomical variants are to be expected. Some variations are well-studied, with the frequencies of the replaced arteries statistically reliable. A good example is the liver supply (because of the increasing number of transarterial therapies and liver donor evaluations). In other cases, case reports with rare arterial findings make it difficult to give reliable numbers.

The classification of arterial variations is usually based on the normal embryological development. During ontogeny, rapid growth occurs with anastomoses between arteries disappearing. However, some of the arteries that are usually present for a short period only may remain throughout life. Furthermore, given that many organs such as the testes and the heart wander during their development, knowledge of their original location may explain certain abnormalities. In this book, no detailed descriptions of the different types are given, only brief explanations. More important are the schematic drawings and the radiographs, which show variations of the origin, the course of the artery, and sometimes the area or portion of the organ supplied. The figures and radiographs are mainly arranged by individual arteries or by the blood supply of a given organ. There is by necessity some overlap, especially in areas like the celiac trunk. The reader looking for a given artery in the index will find all variants of that vessel listed together on a few pages with the corresponding drawings.

The numerous descriptions of single cases of an abnormal artery could not all be cited in the references. Some case reports were selected if a rare individual type was of special interest for any clinical reason or to explain the development of variations of that artery in general. Preference was given to articles reporting large numbers of patients.

Part I

Heart and Thorax

2 Aortic Arch

D. Hortung, K. Hueper

2.1 Development of the Aortic Arch

During the early stages of embryonic development two pairs of aortas are present. The anterior aortas ascend from the heart, turn posteriorly within the first branchial arch, and descend as the posterior aortas. Already in embryos with 3-mm crown-heel length, the beginnings and ends of the paired aortas merge, remaining separate only in the area of the foregut. In each of the six branchial arches, connections develop between the anterior and posterior aortas, the branchial arteries. These arteries do not coexist, the first branchial arteries having already disappeared before the fifth and sixth develop. The fifth branchial artery seems to be present for a few hours only, although a few instances of its persisting have been reported.[1–3] The carotid arteries develop from the cranial part of the anterior and posterior aortas. The posterior aortas give off segmental branches along their segmented body wall: 3 occipital, 7 cervical, and 12 thoracic, etc. All cervical arteries disappear, except for the sixth, which forms the subclavian artery. A longitudinal anastomosis remains on both sides to form the vertebral artery.

Thus, as a rule, the human aortic arch develops in the following way:

1. The left side of the fourth branchial artery forms part of the aortic arch, and the right side forms the beginning of the subclavian artery.
2. Parts of the posterior aortas on both sides atrophy, that is, the area between the third and fourth branchial arteries (left) and the section between the sixth segmental artery and the merged descending aorta (right).

3. The sixth branchial arteries form the beginning of the pulmonary arteries and the ductus arteriosus (Botallo’s duct). The final topographical position of the aortic arch and its branches is a product of differential growth rates of various parts of the arteries, which results in a “migration” and “merging” of branches. The main force behind these changes seems to be the optimization of hemodynamic paths combined with the descending heart.

For developmental and general aspects of the aortic arch, see the literature.[4–15]

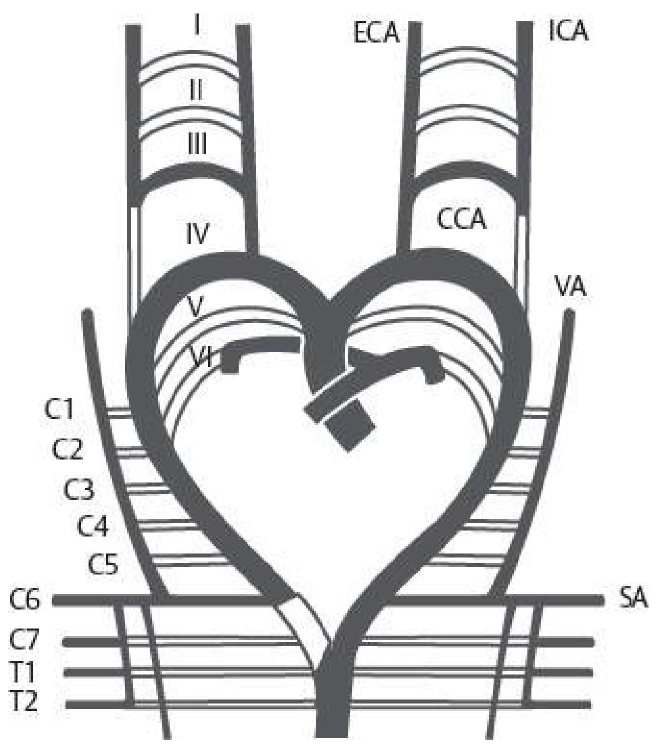

Fig. 2.1 Development of the aortic arch. I–VI, occipital segmental branches; C1–C7, cervical segmental branches; T1–T2, thoracic segmental branches; CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotid artery; SA, subclavian artery; VA, vertebral artery.

2.2 “Normal” Situation (70%)

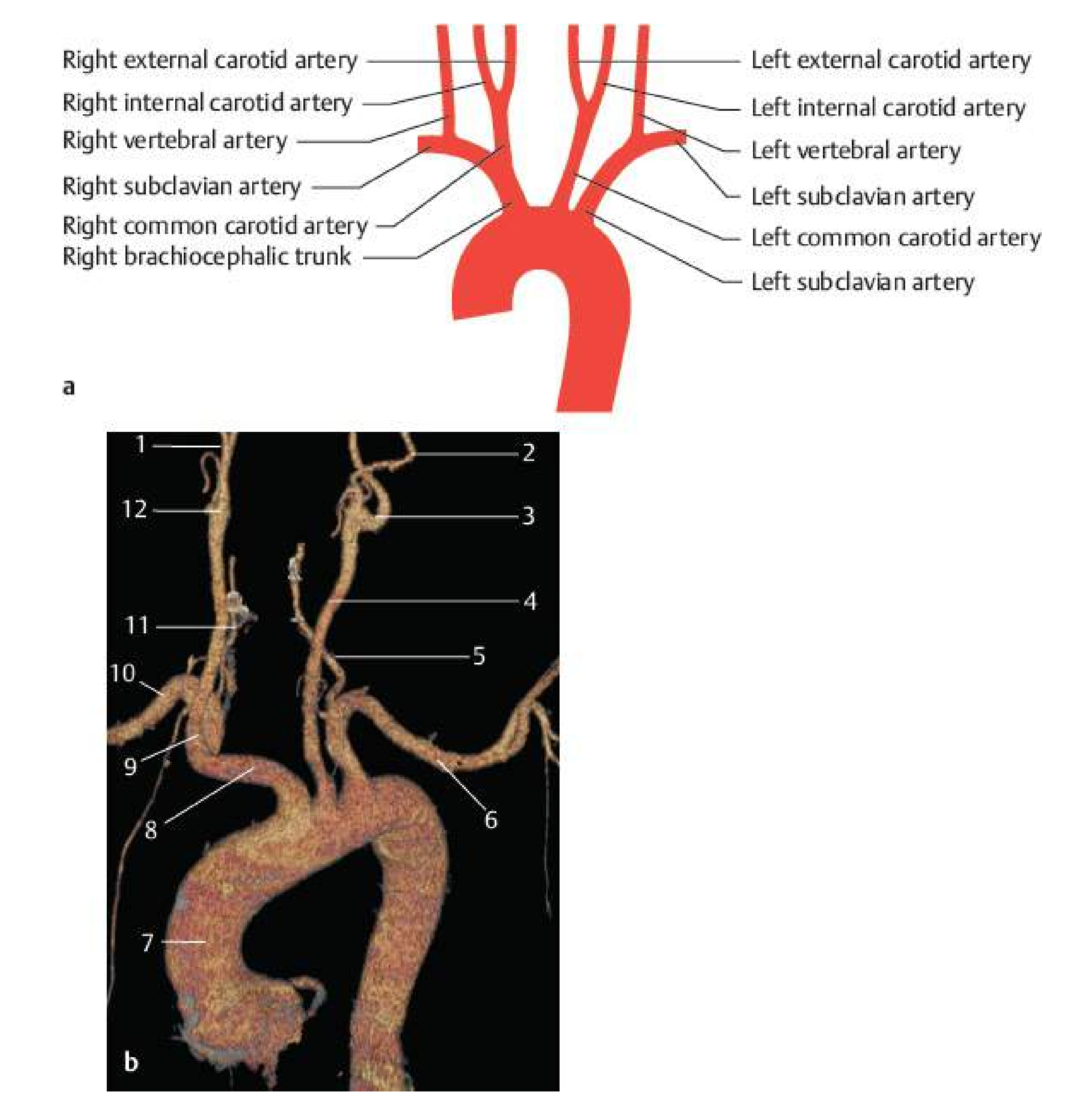

Fig. 2.2 “Normal” situation as given in textbooks (70%). Schematic (**a**) and MRA, VR 3D image, anterior view (**b**). **1** Right external carotid artery; **2** left external carotid artery; **3** left internal carotid artery; **4** left common carotid artery; **5** left vertebral artery; **6** left subclavian artery; **7** aorta; **8** right brachiocephalic trunk; **9** right common carotid artery; **10** right subclavian artery; **11** right vertebral artery; **12** right internal carotid artery.

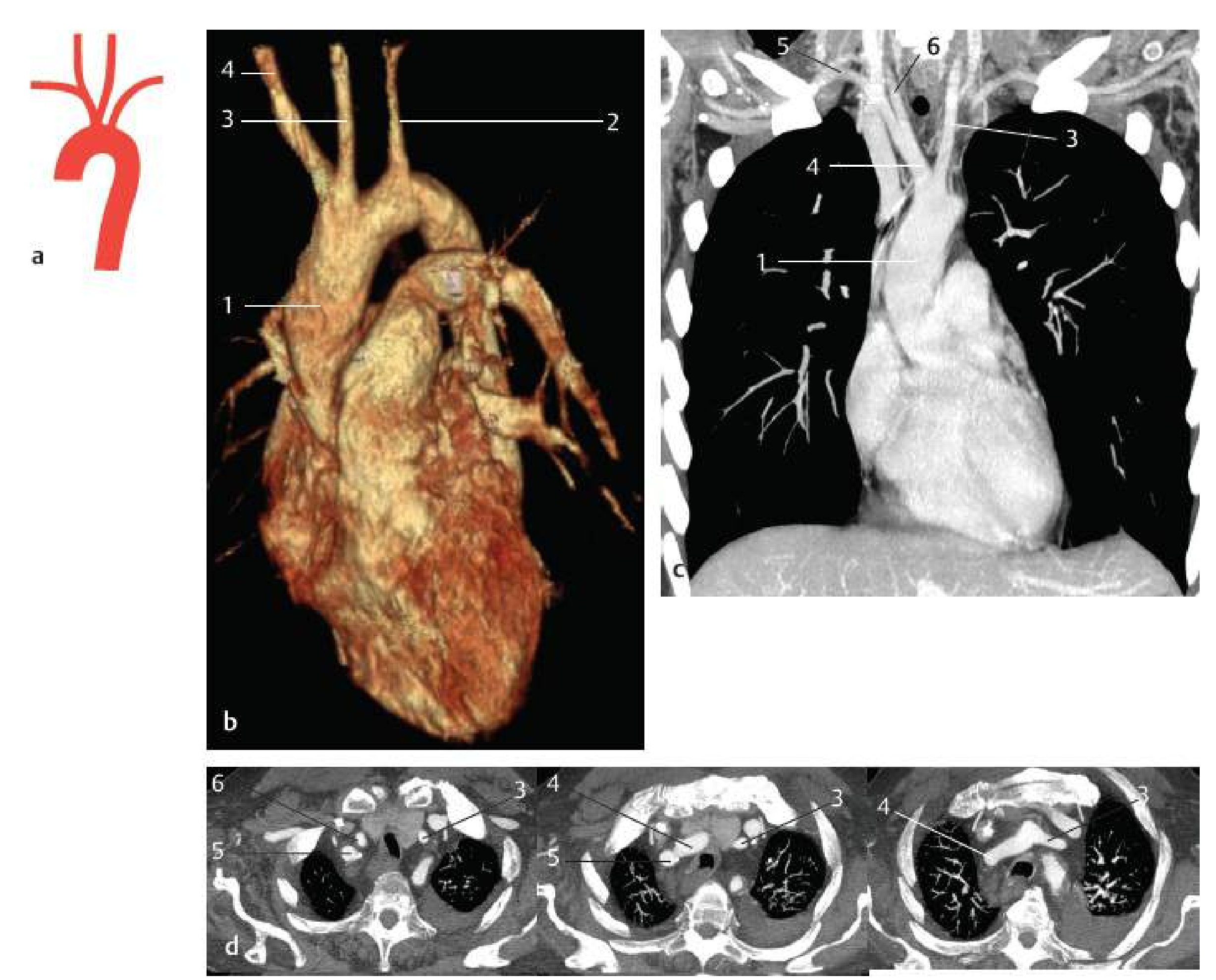

Fig. 2.3 Common origin of the right brachiocephalic trunk and left common carotid artery (~13%). Schematic (**a**) and contrast-enhanced CT images of two patients (**b–d**). ***Patient 1***: VR 3D image, anterior view (**b**); MIP at the level of the common origin of the right brachiocephalic trunk and the left common carotid artery, coronal view (**c**). ***Patient 2***: MIP of the supra-aortic arteries, transverse views (**d**). Patient with left-sided pleural effusion. **1** Aorta; **2** left subclavian artery; **3** left common carotid artery; **4** right brachiocephalic trunk; **5** right subclavian artery; **6** right common carotid artery.

2.3 Anomalies of the Trunk (23%)

The frequencies of the different types depend largely on the method of examination and racial factors (the types illustrated in **Fig 2.3** and **Fig**

2.4 seem to be present more often in blacks than in Caucasians). Some descriptions are difficult to classify and lie between the types shown in Fig. 2.2, Fig. 2.3, and Fig 2.4. According to the literature, the types shown in Figs. 2.2–2.11 cover approximately 93% of all humans.[5,8,14,16–30]

Some types that are considered anomalies in humans are the rule in other mammals; for example, Fig 2.4 occurs in rodents and carnivores, Fig 2.5 in insectivores, Fig 2.6 in elephants, and Fig 2.7 in paired and unpaired ungulates.

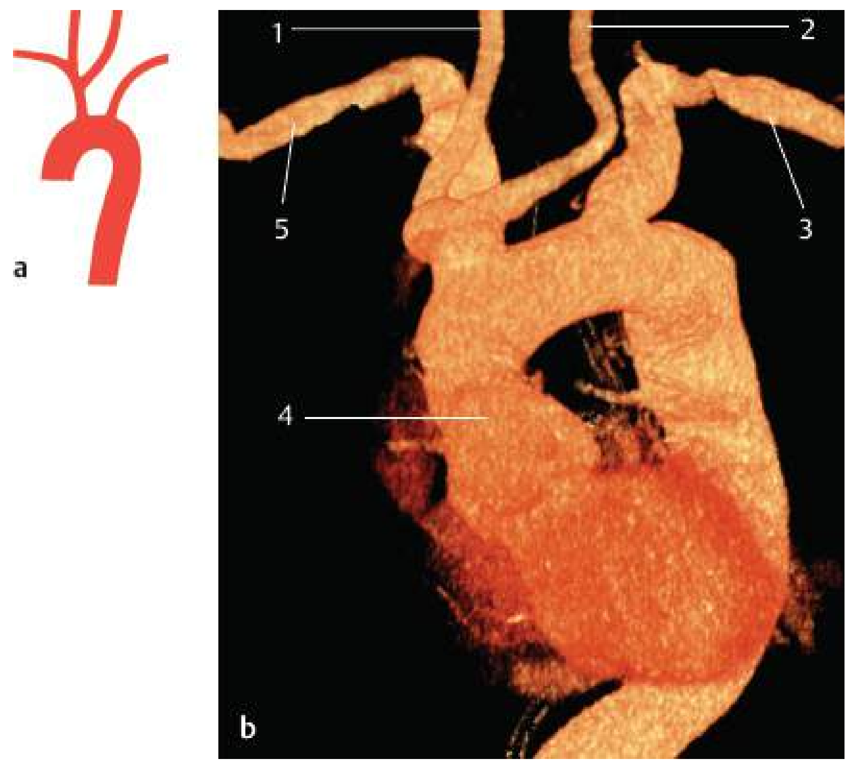

Fig. 2.4 Left common carotid artery originates from the right brachiocephalic trunk (~9%). Schematic (**a**) and contrast-enhanced CT of the thoracic aorta, VR 3D image, anterior view (**b**). **1** Right common carotid artery; **2** left common carotid artery; **3** left subclavian artery; **4** aorta; **5** right subclavian artery.

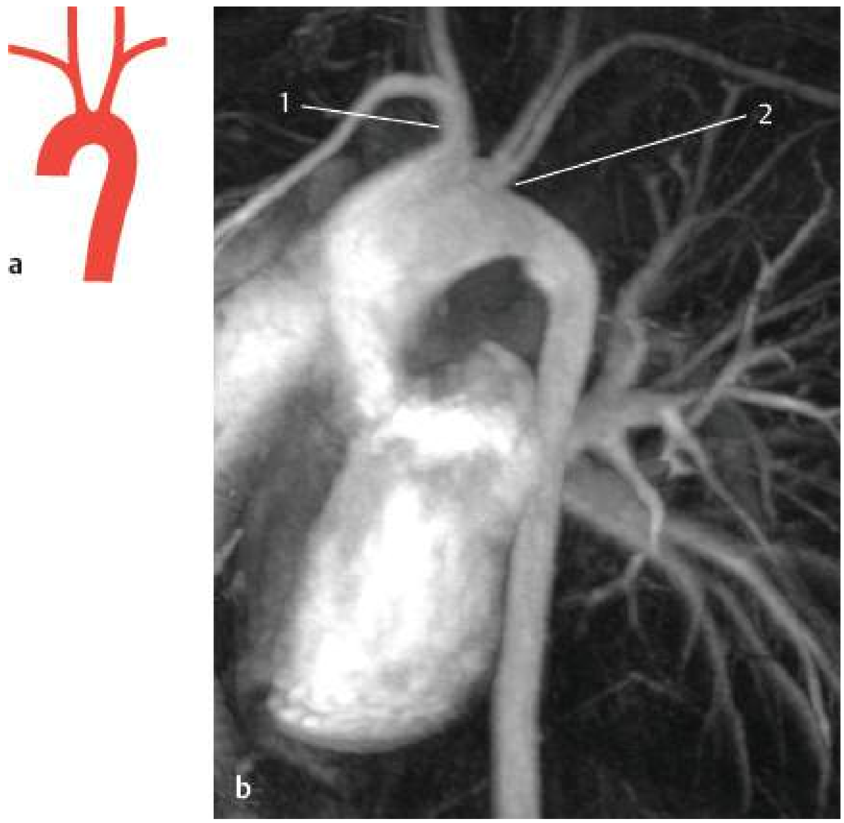

Fig. 2.5 Right and left brachiocephalic trunk (<1%). Schematic (**a**) and MRA, VR 3D image, sagittal oblique view (**b**). **1** Right brachiocephalic trunk; **2** left brachiocephalic trunk.

Fig. 2.6 Trunk formation of both carotid arteries (bicarotid) (<0.1%). Schematic.

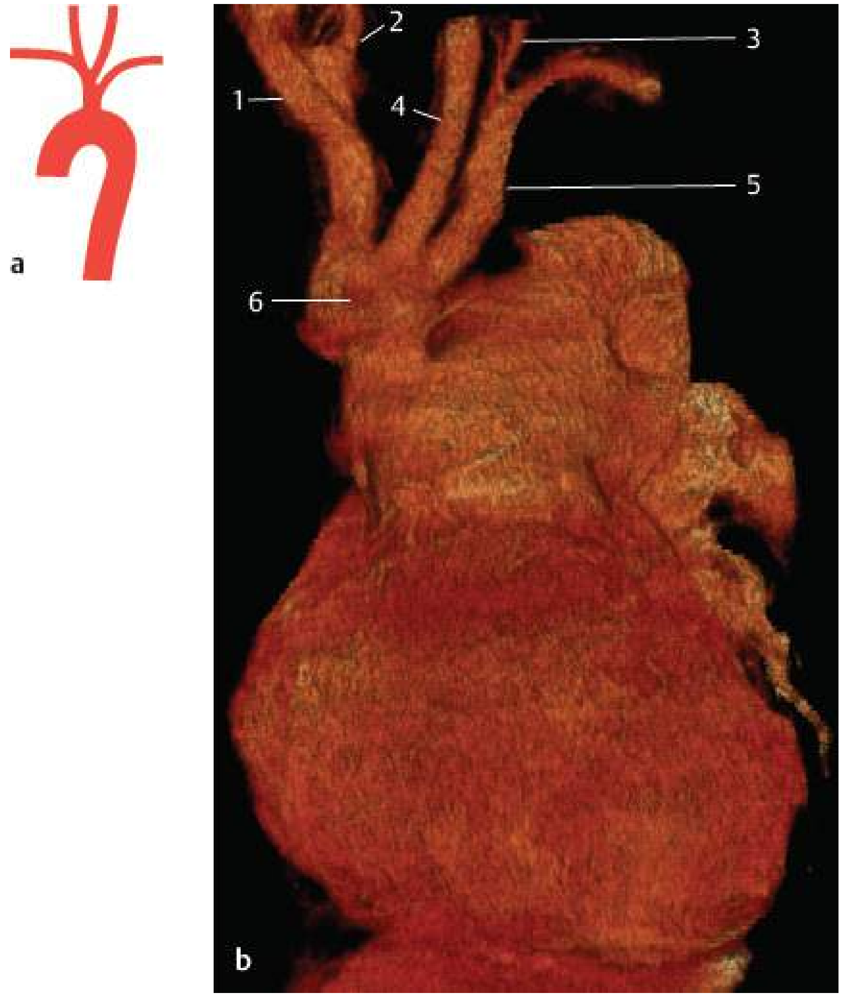

Fig. 2.7 Common brachiocephalic trunk (<0.1%). Schematic (**a**) and contrast-enhanced CT of the thoracic aorta, VR 3D image, anterior view (**b**). The CT image shows the common brachiocephalic trunk in a 24-year-old woman with a truncus arteriosus as a congenital cardiac anomaly. **1** Right subclavian artery; **2** right common carotid artery; **3** left vertebral artery; **4** left common carotid artery; **5** left subclavian artery; **6** common brachiocephalic trunk.

Fig. 2.8 Right subclavian artery originates from a bicarotid trunk (<0.1%). Schematic.

Fig. 2.9 Left subclavian artery originates from a bicarotid trunk (<0.1%). Schematic.

Fig. 2.10 Only a left brachiocephalic trunk (<0.1%). Schematic.

Fig. 2.11 No brachiocephalic trunk (<0.1%). Schematic.

2.4 Vertebral Artery as a Direct Branch of the Aortic Arch (4%)

When a segmental artery persists more cranial than the sixth cervical artery, the left vertebral artery will branch from the aortic arch. In such cases, the vertebral artery enters the vertebral column through a more cranial transverse foramen. The vertebral artery can have two origins when the longitudinal anastomosis to the sixth segmental artery remains open. In extremely rare instances, the right vertebral artery originates from the aortic arch. In such cases, either all the beginning part of the right fourth branchial artery forms the aortic arch or there is a variety of the type shown in Section 2.6 with a subsequent “migration” of the origin of the artery.[31–33]

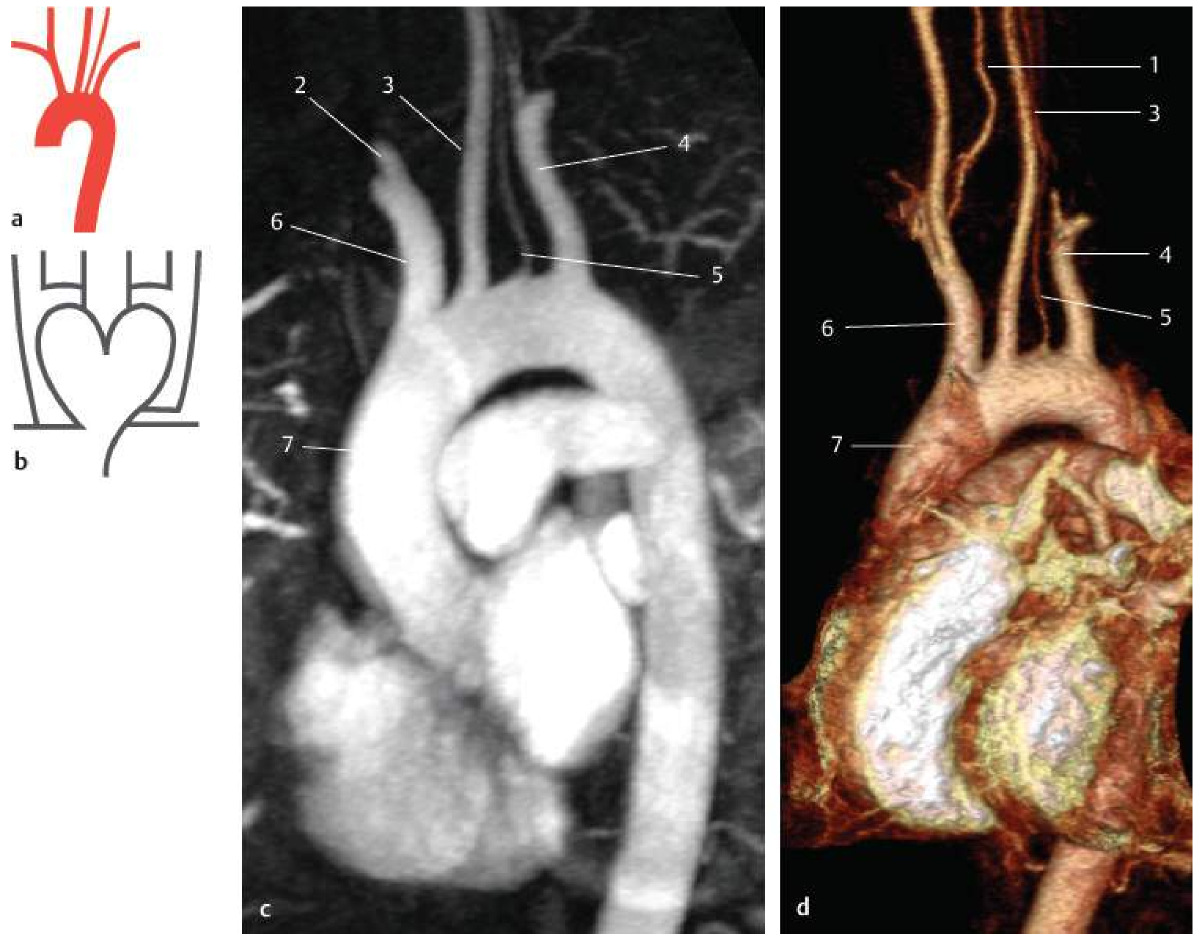

Fig. 2.12 Left vertebral artery as the penultimate branch of the aortic arch (3%). Schematics of the arterial variation (**a**), its development (**b**), and MRA images of the arterial variation (**c,d**), both of the same patient. MIP of the thoracic aorta and the supra-aortic vessels in an oblique sagittal view (**c**), VR 3D image in an oblique sagittal view (**d**). **1** Right vertebral artery; **2** right common carotid artery; **3** left common carotid artery; **4** left subclavian artery; **5** left vertebral artery; **6** right brachiocephalic trunk; **7** aorta.

Fig. 2.13 Left vertebral artery as the penultimate branch of the aortic arch; left common carotid artery originating from the brachiocephalic trunk (<1%). Schematic.

Fig. 2.14 Left vertebral artery as the last branch of the aortic arch (<1%). Schematic.

Fig. 2.15 Left vertebral artery as the last branch of the aortic arch; left common carotid artery originating from the brachiocephalic trunk (<0.1%). Schematic.

Fig. 2.16 Left vertebral artery as the last branch of the aortic arch; a common brachiocephalic trunk (<0.1%). Schematic.

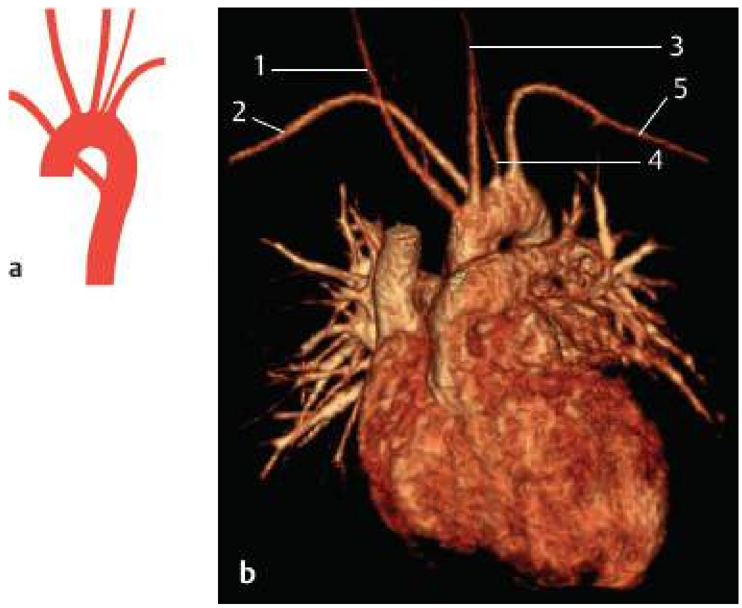

Fig. 2.17 Vertebral artery branches before the left subclavian artery, but the last branch of the aortic arch is the right subclavian artery (<0.1%). Schematic (**a**) and MRA, VR 3D image, anterior view (**b**). **1** Right common carotid artery; **2** right subclavian artery; **3** left common carotid artery; **4** left vertebral artery; **5** left subclavian artery.

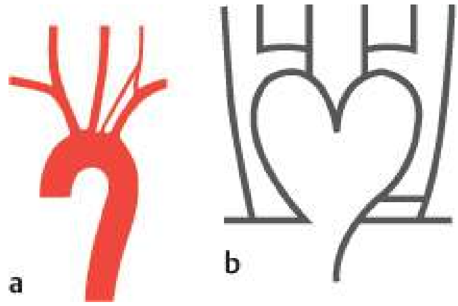

Fig. 2.18 Two roots of the vertebral artery, one penultimate branch of the aortic arch (<1%). Schematics of the arterial variation (**a**) and its development (**b**).

Fig. 2.19 Both vertebral arteries directly branch from the aortic arch (<0.1%). Schematic.

2.5 Arteria Thyroidea Ima as a Direct Branch of the Aortic Arch (1%)

The overall frequency of the lowest thyroid artery (arteria thyroidea ima) is approximately 6%: it arises from the brachiocephalic trunk in 3% of all cases; from the right common carotid artery in 1%; from the aortic arch in 1%; and less frequently from the internal thoracic artery, subclavian artery, and inferior thyroid scapular artery. Two arteria thyroidea ima have also been described. This artery is of importance in surgeries performed caudal to the isthmus of the thyroid gland. For general features, see the literature.[8,9,34–40]

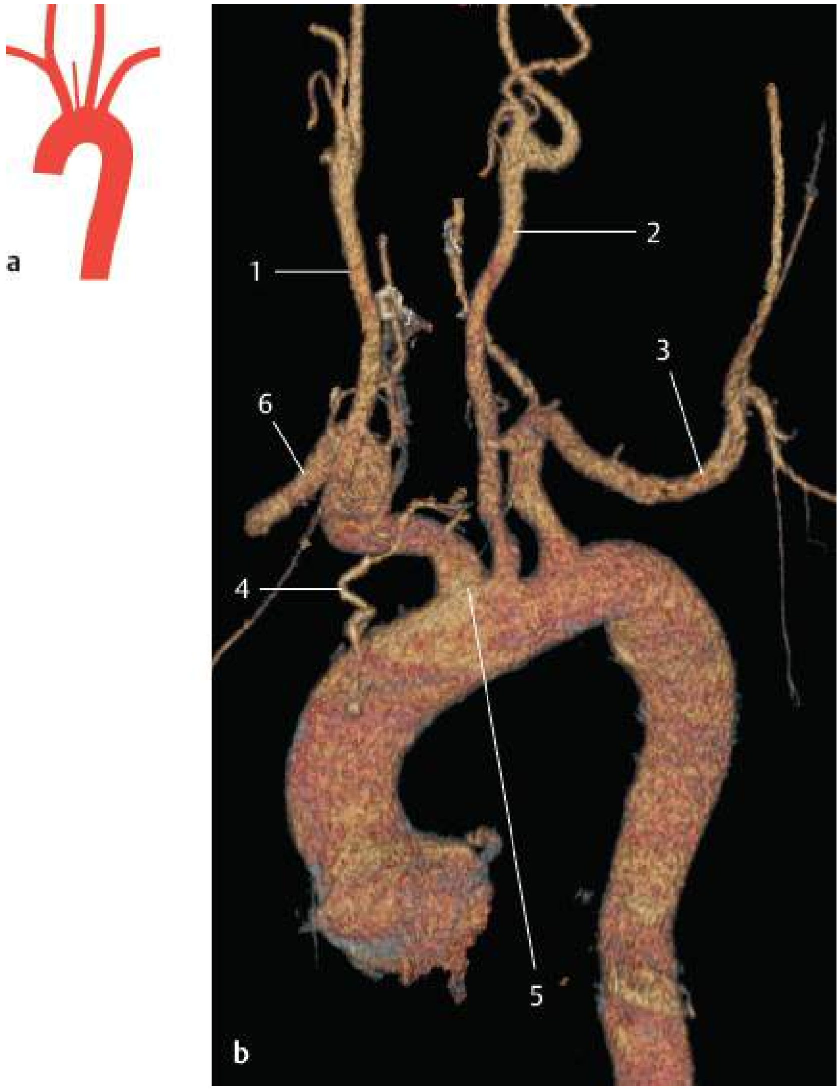

Fig. 2.20 Arteria thyroidea ima as a direct branch of the aortic arch (1%). Schematic (**a**) and contrast-enhanced CT, VR 3D image, anterior view (**b**). **1** Right common carotid artery; **2** left common carotid artery; **3** left subclavian artery; **4** arteria thyroidea ima; **5** right brachiocephalic trunk; **6** right subclavian artery.

2.6 Right Subclavian Artery as the Last Branch of the Aortic Arch (Arteria Lusoria) (1%)

In this situation, the right subclavian artery always turns to the right behind the other branches. It is located behind the esophagus in 80%

of all cases, between the esophagus and trachea in 15%, and in front of the trachea or the main bronchi in 5%. This position results in dysphagia or dyspnea.[8,35,40–44] In most cases, the right recurrent laryngeal nerve is absent, but there are direct branches to the trachea and esophagus from the vagus. If the right vertebral artery branches from the right common carotid artery (see **Fig. 2.24a**), a nerve, comparable to the recurrent laryngeal nerve, winds around the artery.

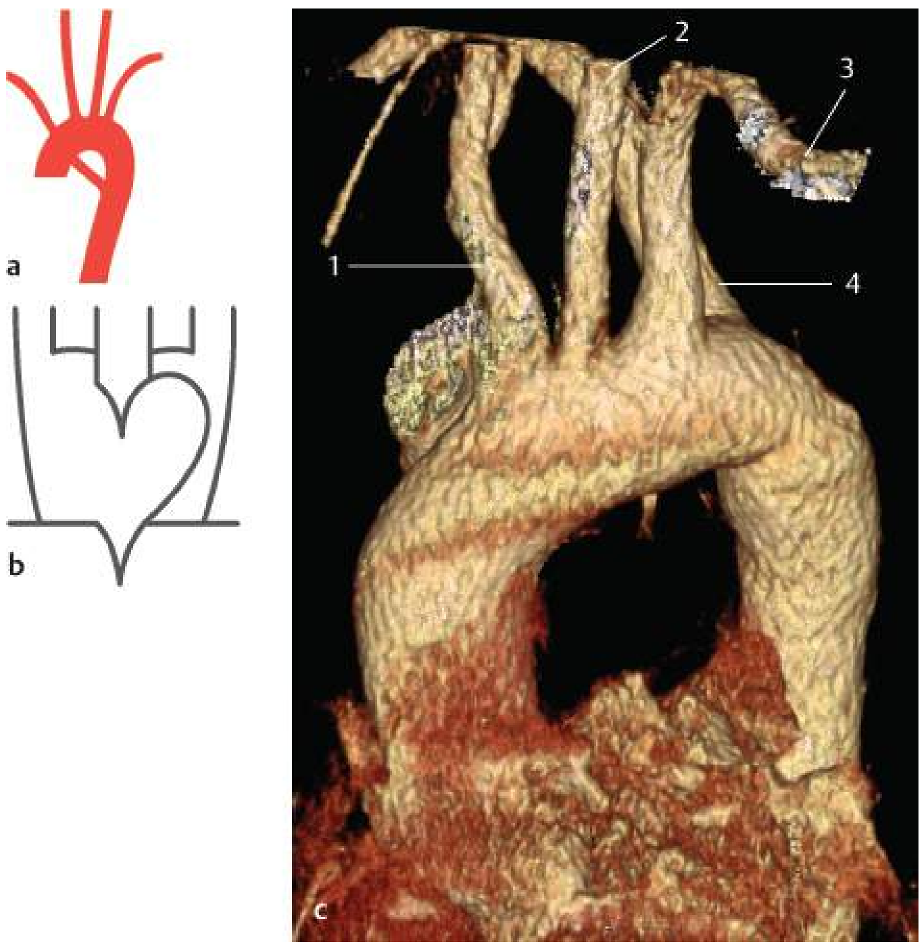

Fig. 2.21 Right subclavian artery as the last branch of the aortic arch, other arteries originate normally (<1%). Schematics of the arterial variation (**a**), its development (**b**), and contrast-enhanced CT of the arterial variation (**c**), VR 3D image, anterior view. The scan field of view in **c** is limited to the thorax, so that the supra-aortic vessels are not displayed in their entire course. **1** Right brachiocephalic trunk; **2** left

common carotid artery; **3** left subclavian artery; **4** right subclavian artery.

Fig. 2.22 Right subclavian artery as the last branch of the aortic arch combined with a bicarotid trunk (<1%). Schematic.

Fig. 2.23 Right subclavian artery as the last branch of the aortic arch combined with a left subclavian artery from the bicarotid trunk (<0.1%). Schematic.

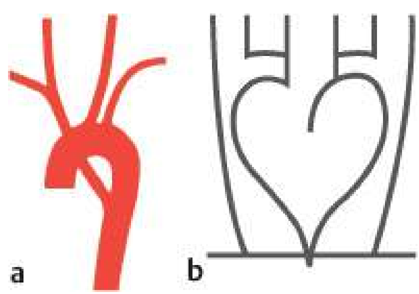

Fig. 2.24 Right brachiocephalic trunk as the last branch of the aortic arch (<0.1%). Schematic of the arterial variation (**a**) and its development (**b**).

2.7 Right-Sided Aortic Arch (<0.1%)

The persistence of the right fourth branchial artery results in this anomaly, which is more frequent in Fallot's tetralogy.[5,45–54] The right-sided aortic arch is the rule in birds and in certain reptiles.

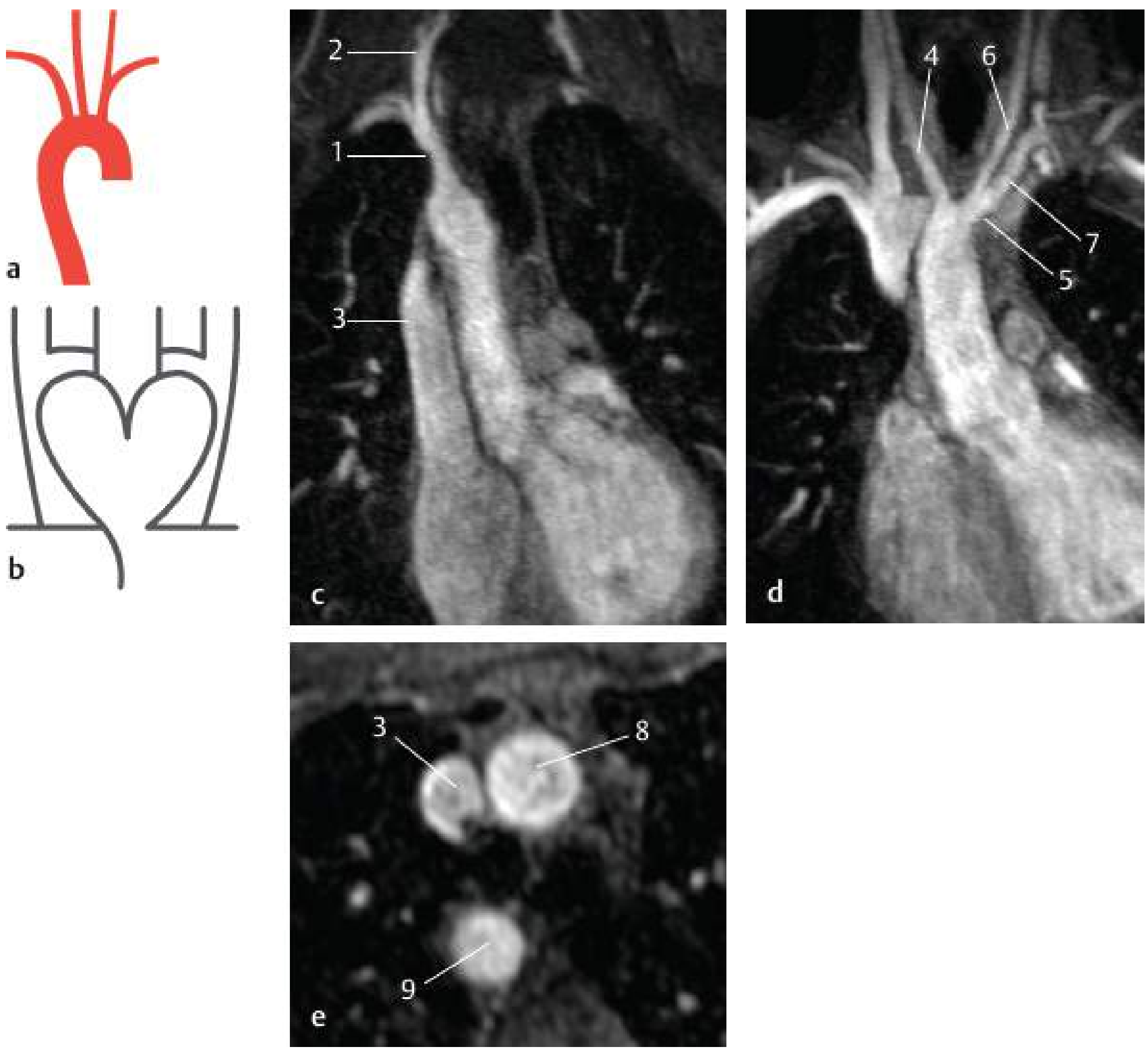

Fig. 2.25 Mirror image of the type shown in Fig. 2.2 (<0.1%). Schematics of the arterial variation (**a**) and its development (**b**), and MRA images showing the arterial variation (**c–e**). MIPs in coronal planes, anterior view (**c**), posterior view (**d**), and transverse view at the level of the aortic arch (**e**). **1** Right subclavian artery; **2** right vertebral artery; **3** superior vena cava; **4** right common carotid artery; **5**

brachiocephalic trunk; **6** left common carotid artery; **7** left subclavian artery; **8** ascending aorta; **9** right descending aorta.

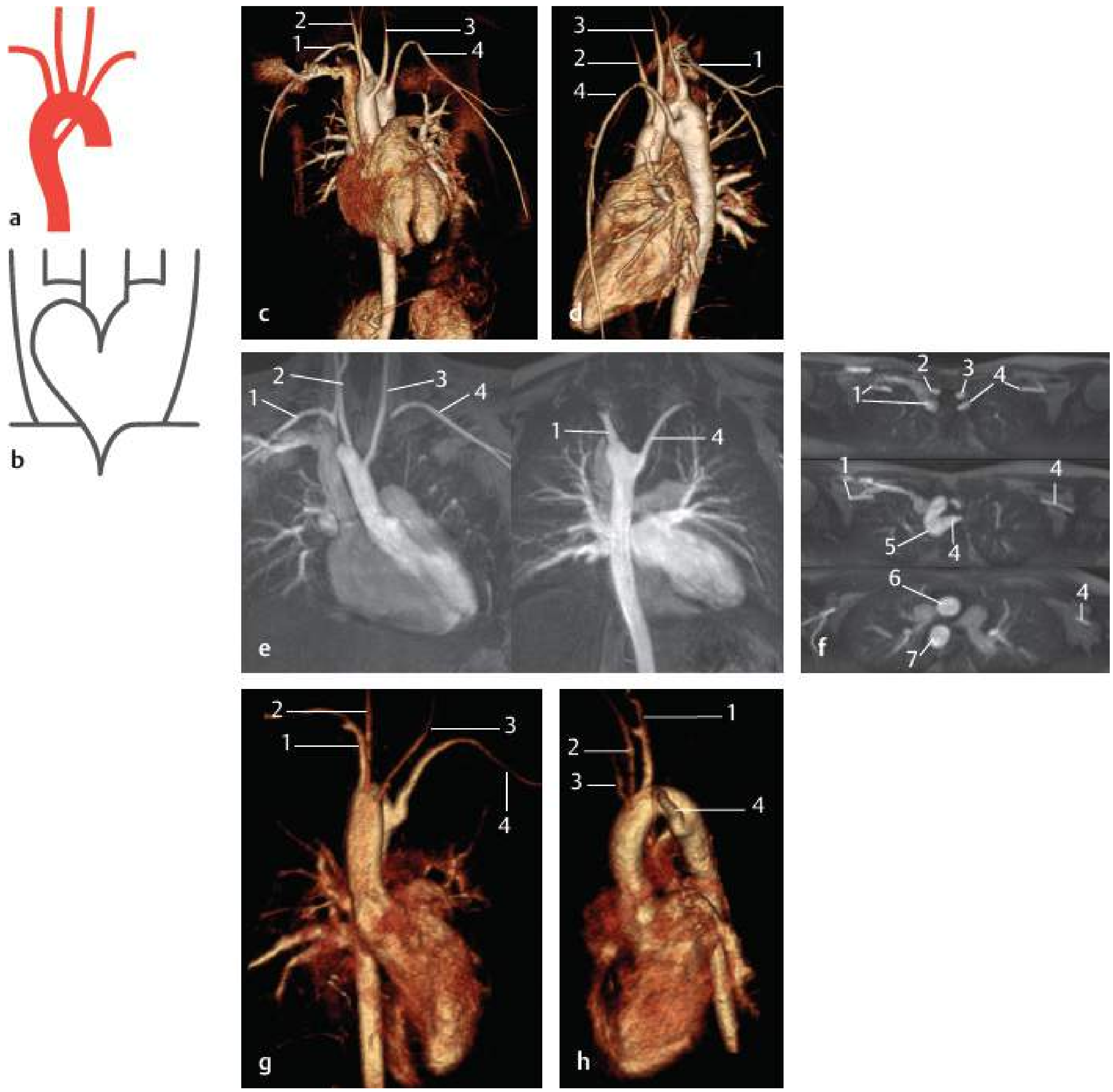

Fig. 2.26 Mirror image of the type shown in Fig. 2.21a (<0.1%). Schematics of the arterial variation (**a**) and its development (**b**), and MRA images of two patients showing the arterial variation (**c-h**). ***Patient 1***: VR 3D images in anterior (**c**) and lateral (**d**) views, MIPs in coronal planes from anterior to posterior (**e**), and transverse views of the supra-aortic vessels and the aortic arch (**f**). ***Patient 2***: VR 3D images in oblique views (**g,h**). **1** Right subclavian artery; **2** right

common carotid artery; **3** left common carotid artery; **4** left subclavian artery; **5** right aortic arch; **6** ascending aorta; **7** right descending aorta.

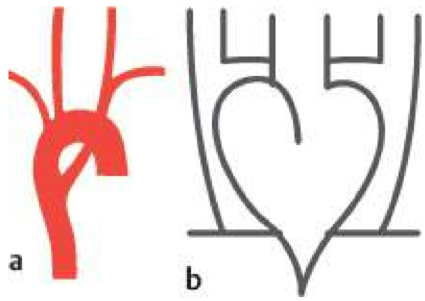

Fig. 2.27 Mirror image of the type shown in Fig. 2.24a (<0.1%). Schematics of the arterial variation (**a**) and its development (**b**).

2.8 Double Aortic Arch (<0.1%)

Most of these cases must be classified as malformations, as they have been reported to cause severe functional disturbances of the trachea and esophagus. However, some rare cases were detected only by chance. Both arches often have different lumens or one aortic arch can be replaced by only a fibrous band. These malformations are often combined with heart defects or a patent ductus arteriosus.[4,5,55–66] Double aortic arches are the rule in all branchial breathing vertebrates and also occur in some reptiles.

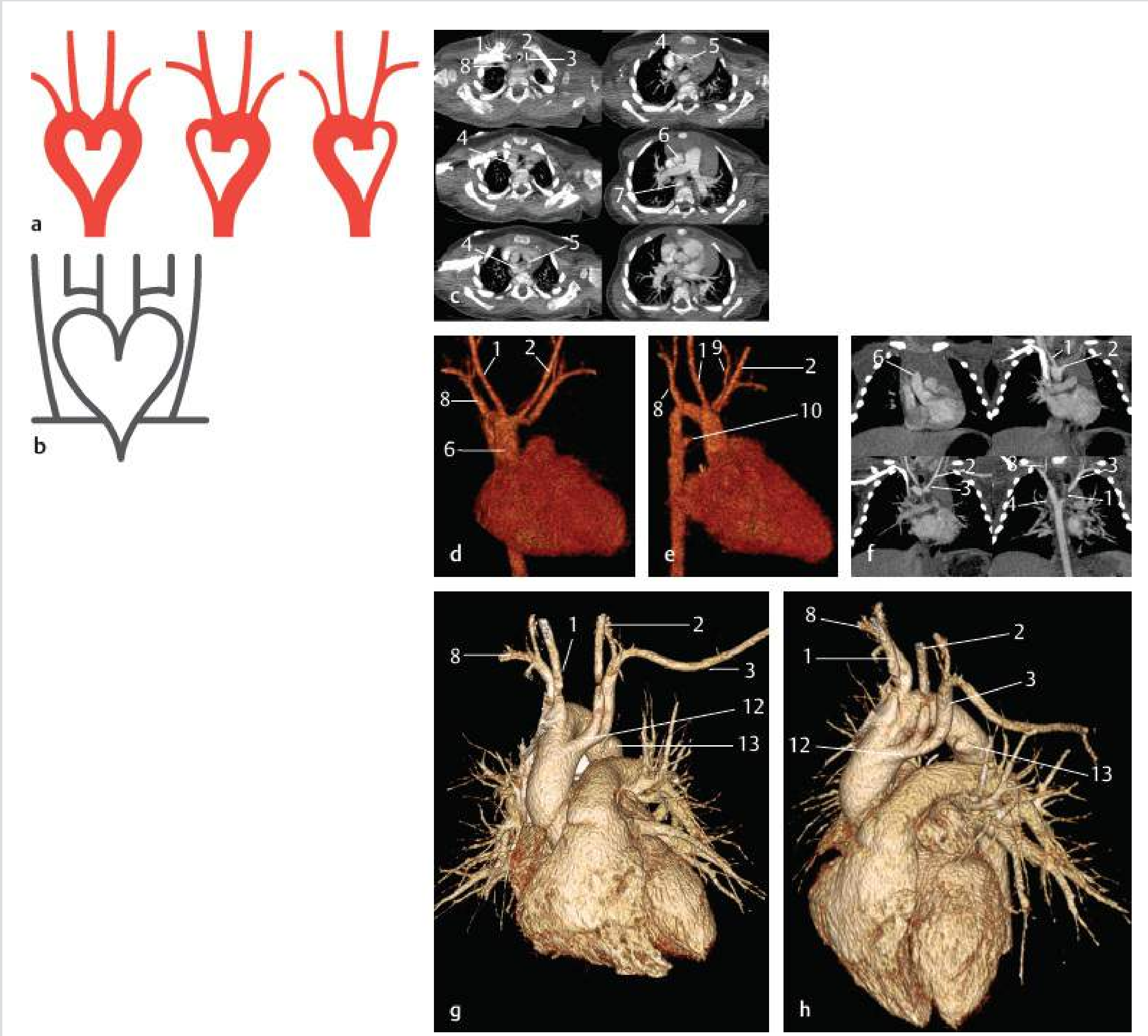

Fig. 2.28 Double aortic arch with same lumens or different lumens of both sides (<0.1%). Schematics of the arterial variation (**a**) and its development (**b**), and contrast-enhanced CT images of the thoracic aorta from three patients (**c-h**). ***Patient 1*** (13-month-old boy): the lumen of the left aortic arch is small compared to the right aortic arch. Transverse views from superior to inferior (**c**). ***Patient 2*** (7-week-old boy): the right aortic arch is replaced by a fibrous band with a dilated diverticulum at the insertion to the descending aorta; VR 3D images in anterior (**d**) and lateral (**e**) views, and MIPs in coronal planes from anterior to posterior (**f**). ***Patient 3***: VR 3D images in anterior (**g**) and oblique lateral (**h**) views. **1** Right common carotid artery; **2** left common carotid artery; **3** left subclavian artery; **4** right aortic arch; **5** left aortic

arch; **6** ascending aorta; **7** right descending aorta; **8** right subclavian artery; **9** left vertebral artery; **10** incomplete right aortic arch; **11** left aortic arch = fibrous band; **12** left brachiocephalic trunk; **13** incomplete left aortic arch.

2.9 Circumflex Aortic Arch (<0.1%)

Paramedian merging of the primitive posterior aortas, the tension of an atypical ductus arteriosus (Botallo's duct), or a rudimentary double aortic arch can all result in such a formation.[5,45,48,67–71] Obviously, these types are more frequent in cases of an arteria lusoria (Section 2.6) or a right-sided aortic arch (Section 2.7) in which the caudal instead of the cranial part of the fourth branchial artery persists. The anomalies in Section 2.9 are extremes that have been described, also as regards the loss of the last branch (**Fig. 2.30**, **Fig. 2.31**, **Fig. 2.33**, and **Fig 2.34**).

Fig. 2.29 Left circumflex aortic arch, otherwise the type shown in Fig. 2.2 (<0.1%). Schematic.

Fig. 2.30 Left circumflex aortic arch, otherwise the type shown in Fig. 2.21a (<0.1%). Schematic.

Fig. 2.31 Left circumflex aortic arch, otherwise the type shown in Fig. 2.24a (<0.1%). Schematic.

Fig. 2.32 Right circumflex aortic arch, otherwise the type shown in Fig. 2.25a (<0.1%). Schematic.

Fig. 2.33 Right circumflex aortic arch, otherwise the type shown in Fig. 2.26a (<0.1%). Schematic.

Fig. 2.34 Right circumflex aortic arch, otherwise the type shown in Fig. 2.27a (<0.1%). Schematic.

2.10 Other Variations of the Aortic Arch (<0.1%)

The sequence of branches can vary due to the different growth rates of individual parts of the vessels. The subclavian arteries are pulled downward by the descending heart, although they are fixed at the upper outlet of the thorax. Many more combinations are possible than are listed. The so-called low division of the carotid artery can be explained by either the first part becoming part of the aortic arch or the third branchial artery disappearing and the part of the primitive posterior aorta between the third and fourth branchial arteries persisting. The latter possibility is supported by cases in which the internal carotid artery is totally absent and the common carotid artery alone forms the external carotid artery.

The branches of the costocervical trunk (deep cervical and supreme intercostal arteries) correspond to the primitive segmental arteries (C7, Th1, and Th2). Normally, they no longer have connections to the aorta and are combined by a longitudinal anastomosis to the subclavian artery.

If the heart descends less caudally than is normal, the so-called cervical aortic arch results.[72–75] Thus, the topographical position of the aortic arch varies in relation to the vertebral column. Finally, it must be stressed that only variations, not malformations, have been described. The many malformations, for example, transposition of the large vessels, the common arterial trunk, the persistent ductus arteriosus, and the coarctation of the aorta, were excluded. Some references deal with the so-called interrupted aortic arch only because this can be explained by the same embryological concept.[5,76–87]

Fig. 2.35 Left subclavian artery originates before the left common carotid artery (<1%). Schematic.

Fig. 2.36 Right subclavian artery originates behind the common carotid artery (<1%). Schematic.

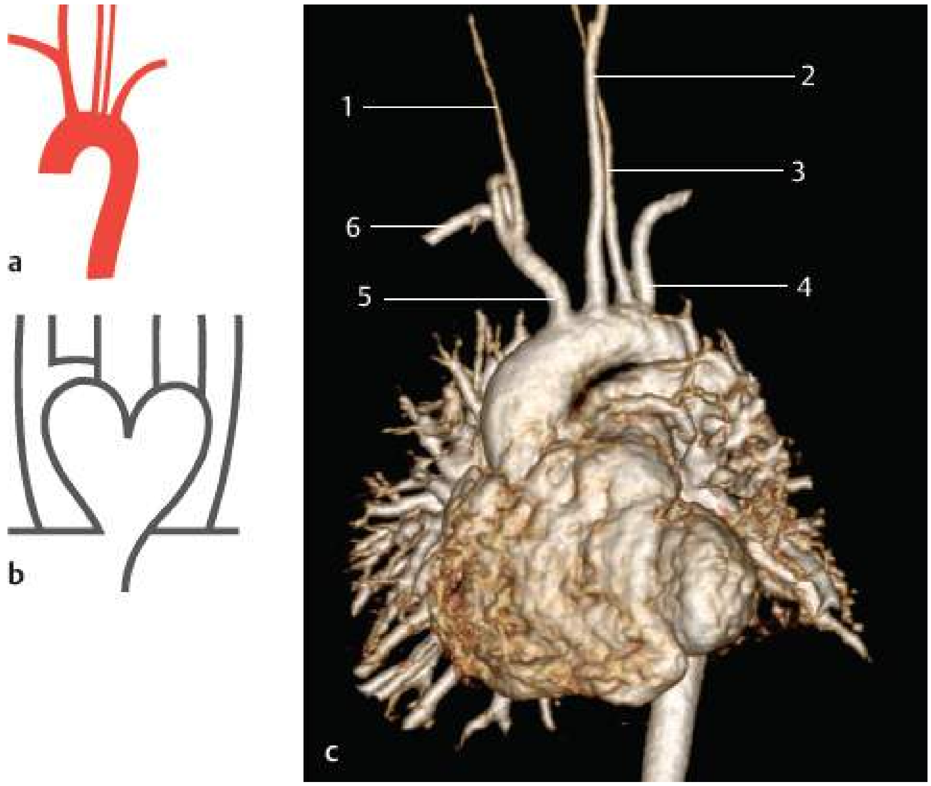

Fig. 2.37 Left external and left internal carotid arteries are separate, direct branches of the aorta (<0.1%). Schematics of the arterial variation (**a**) and its development (**b**), and MRA of the arterial variation, VR 3D image, anterior view (**c**). **1** Right common carotid artery; **2** left external carotid artery; **3** left internal carotid artery; **4** left subclavian artery; **5** right brachiocephalic trunk; **6** right subclavian artery.

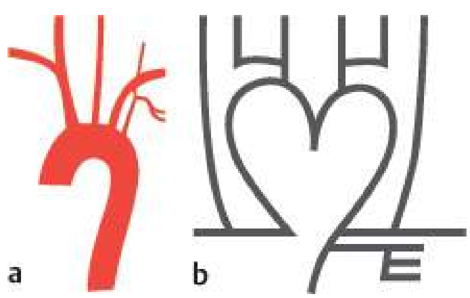

Fig. 2.38 Left costocervical trunk as a direct branch of the aortic arch (<0.1%). Schematics showing the arterial variation (**a**) and its development (**b**).

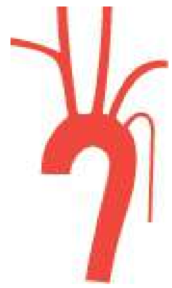

Fig. 2.39 Left internal thoracic artery as a direct branch of the aortic arch (<0.1%). Schematic.

Fig. 2.40 The artery of the thymus is a direct branch of the aortic arch (<0.1%). Schematic.

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3 Coronary Arteries

D. Hortung, K. Hueper

In the past two decades, the coronary arteries have been studied extensively by coronary angiography, resulting in numerous case reports on different anomalies. For references, see recent books, reviews, or descriptions of anomalies of specific patterns of general interest.[1–21]

The anomalies of coronary arteries can be classified by:

- The presence of accessory branches from the aorta and minor deviations in the origins.
- The presence of only a single ostium of the coronary arteries.
- The origin from the pulmonary trunk.
- Anastomoses with other arteries
- The variability of the posterior interventricular branch.

Many anomalies have no clinical significance under normal circumstances, but they can explain differences in symptoms and electrocardiography findings caused by sclerotic plaques in an anomalous coronary artery or during heart surgery. Anomalous coronary arteries seem to occur more frequently in cases of anomalies of the heart.[5] These are not usually included in the percentages given in the figures.

3.1 "Normal" Situation as Described in Textbooks (~60%)

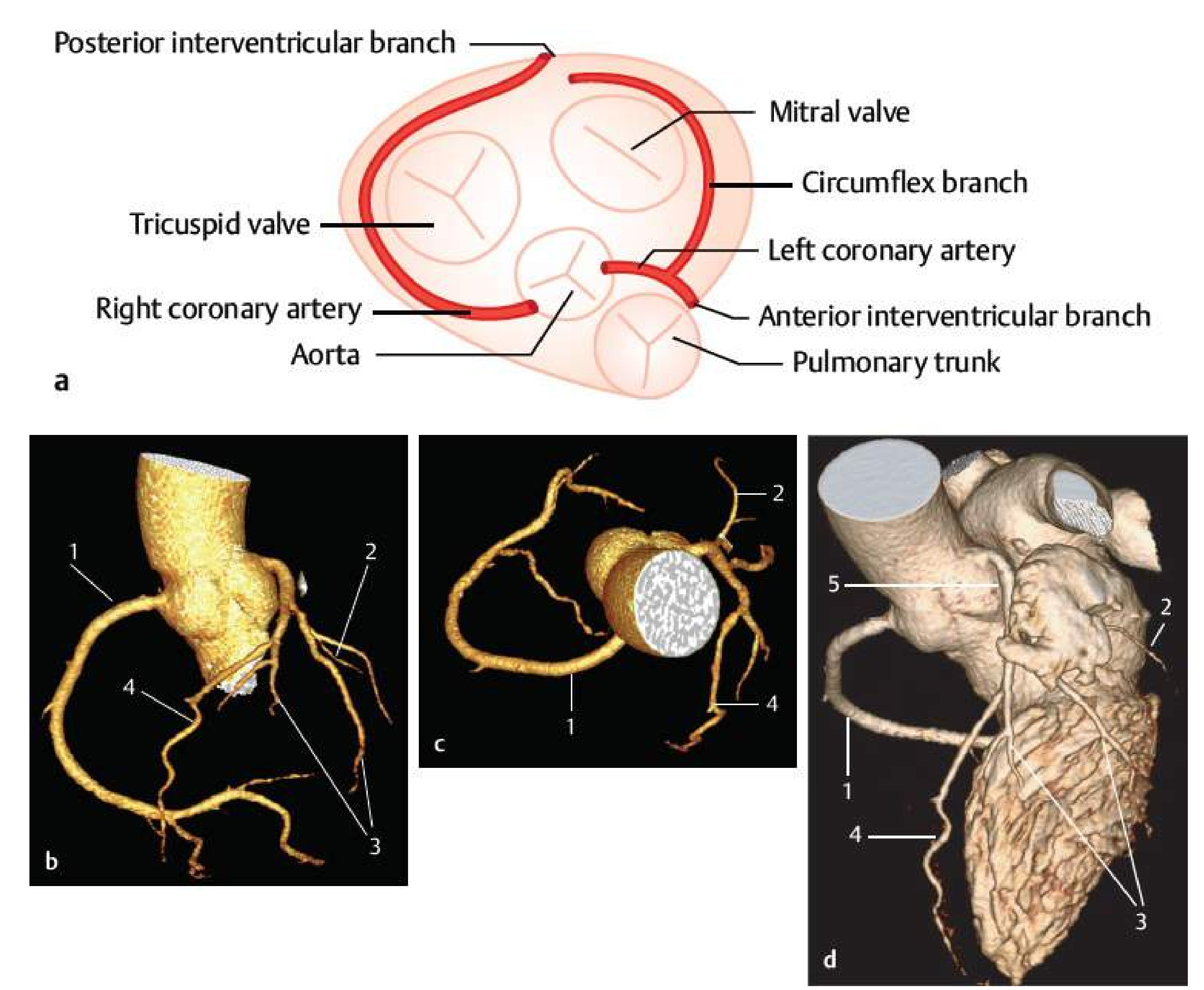

Fig. 3.1 “Normal” situation as described in textbooks (60%). Schematic (**a**) and coronary CTA (**b-d**). VR 3D images in anterior (**b**), superior (**c**), and anterior oblique (**d**) views. **1** Right coronary artery; **2** circumflex branch; **3** diagonal branch; **4** anterior interventricular branch; **5** left coronary artery.

3.2 Accessory Arteries and Anomalies of the Origin of the Aorta (~38%)

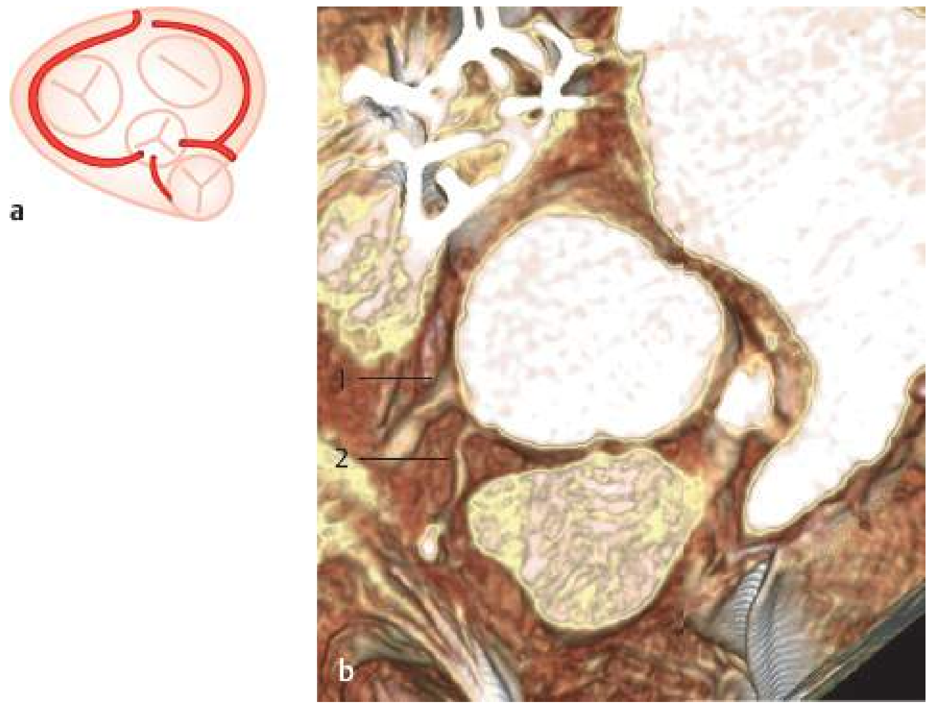

Fig. 3.2 Artery to the beginning of the pulmonary artery: conus artery (~37%). Schematic (**a**) and CTA of the thoracic aorta, VR 3D image cut at the level of the aortic root, superior view (**b**). **1** Right coronary artery; **2** conus artery.

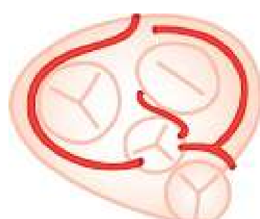

Fig. 3.3 Additional artery to the septum (a. septi ventriculorum) (<0.1%). Schematic.

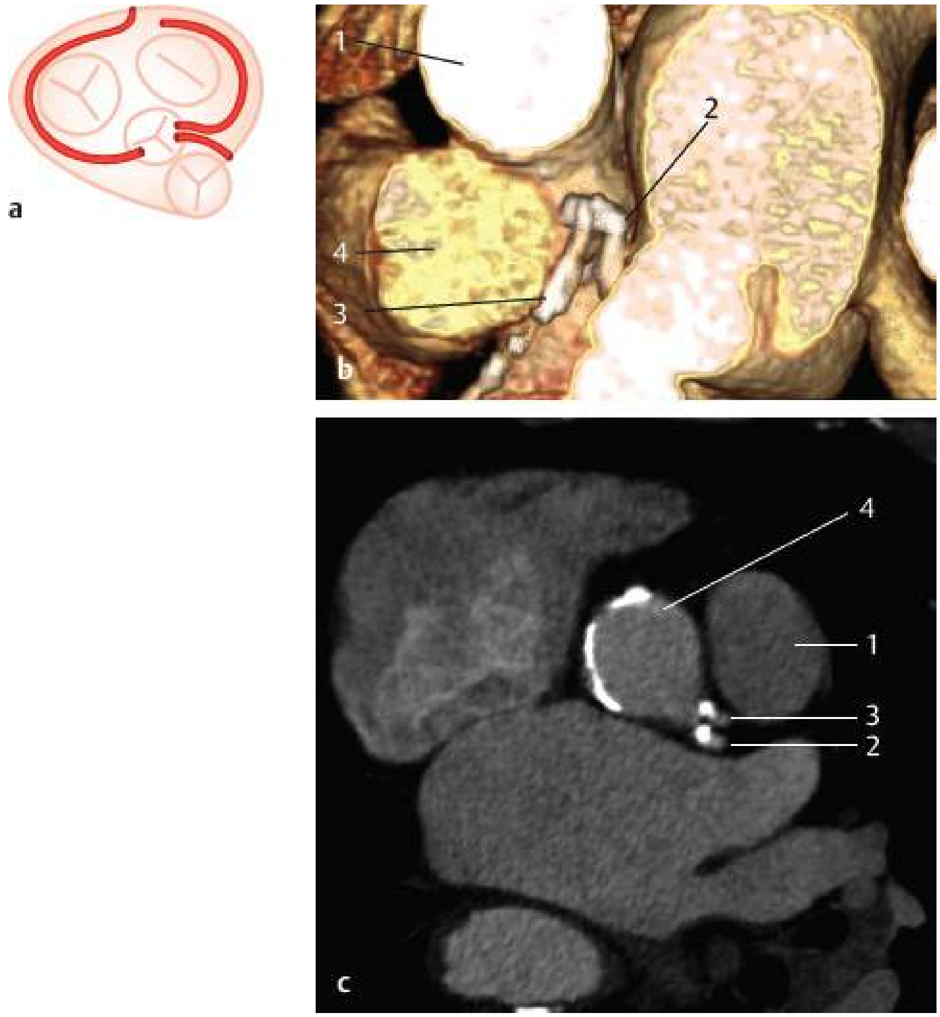

Fig. 3.4 Separate origin of the anterior interventricular branch and circumflex branch of the left coronary artery (<1%). Schematic (**a**) and contrast-enhanced CT in a patient with calcified atherosclerotic lesions of the ascending aorta and the coronary arteries (**b,c**). VR 3D images cut at the level of the aortic root, superior (**b**) and oblique transverse (**c**) views. **1** Pulmonary trunk; **2** circumflex branch; **3** anterior interventricular branch; **4** aorta.

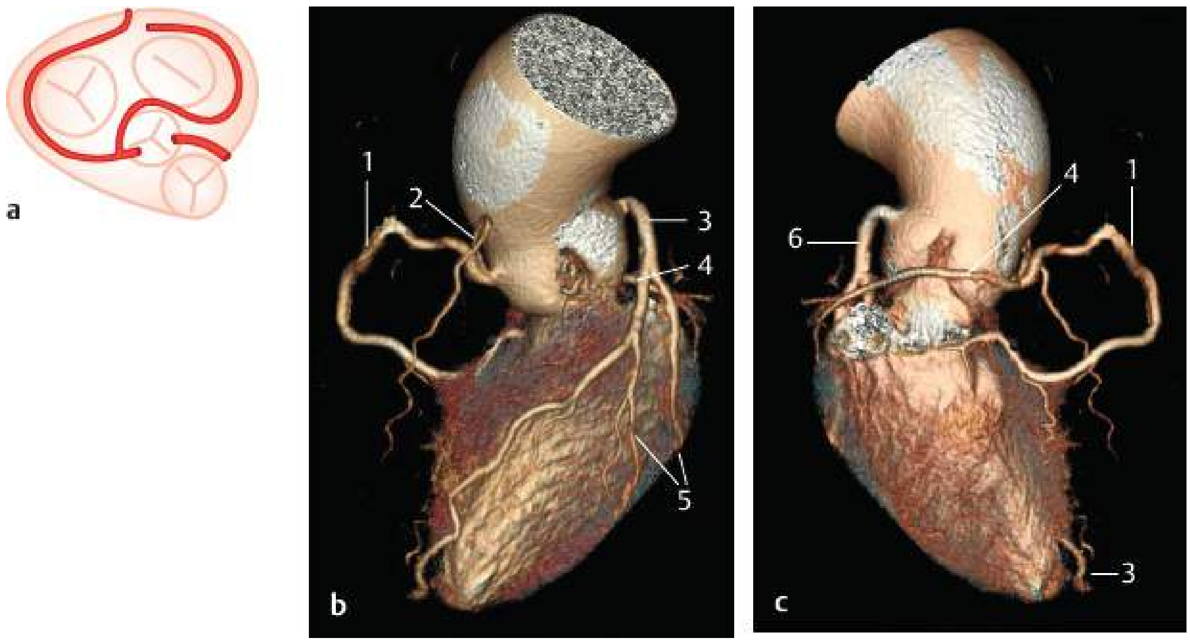

Fig. 3.5 Left circumflex branch but as a branch of the right coronary artery (<1%). Schematic (**a**) and coronary CTA (**b,c**). VR 3D images, anterior (**b**) and posterior (**c**) views. **1** Right coronary artery; **2** right ventricular branch; **3** anterior interventricular branch; **4** circumflex branch; **5** diagonal branches; **6** left coronary artery.

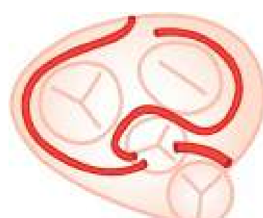

Fig. 3.6 Left circumflex branch originates separately on the right side of the aorta (<0.1%). Schematic.

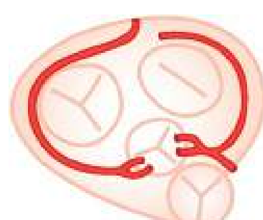

Fig. 3.7 Two separate origins of both coronary arteries (delta type) (<0.1%). Schematic.

3.3 Only One Coronary Artery Arising from the Aorta (<1%)

If the aorta has only one coronary orifice, two different types of coronary arteries can be distinguished:

– Only the first parts of both coronary arteries form a trunk, but otherwise all normal branches are present.[6,18,22–32]
– One coronary artery is totally absent, resulting in an anomalous blood supply to the whole heart by only one coronary artery.[33] Comparable symptoms are found in patients in whom both coronary arteries originate from the same sinus of Valsalva.[18,22,26,31,34–37] A coronary artery running between the aorta and pulmonary trunk or intramurally can cause intermittent angina.[18,38–41] Angiological studies have shown that more patients have only one ostium for one coronary artery than have been reported in anatomical studies. Since coronary angiographies are performed only on patients with angina, a select group of patients are investigated. An anomalous course of a single coronary artery can cause exertional angina, requiring coronary angiography.

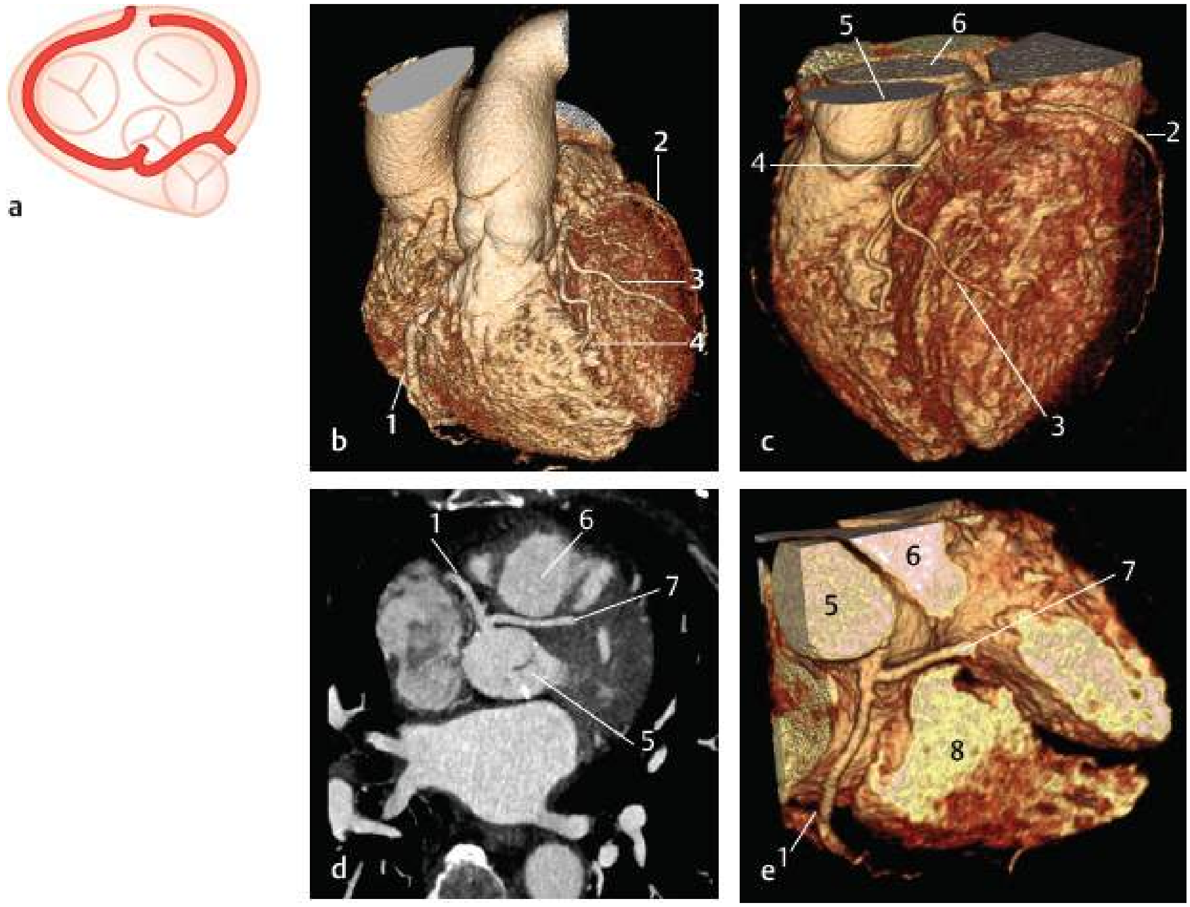

Fig. 3.8 Left coronary artery branches from the right coronary artery and runs anterior to the aorta (<0.1%). Schematic (**a**) and coronary CTA (**b-e**). VR 3D images in oblique anterior view (**b,c**); MIP in oblique transverse view at the origin of the coronary artery (**d**); and VR 3D image cut at the level of the aortic root, superior view (**e**). **1** Right coronary artery; **2** circumflex branch; **3** diagonal branches; **4** anterior interventricular branch; **5** aorta; **6** pulmonary trunk; **7** left coronary artery; **8** right ventricle.

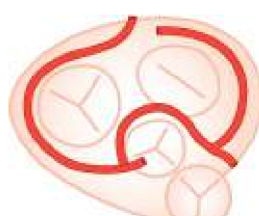

Fig. 3.9 Left coronary artery branches from the right coronary

artery and runs posterior to the aorta (<1%). Schematic.

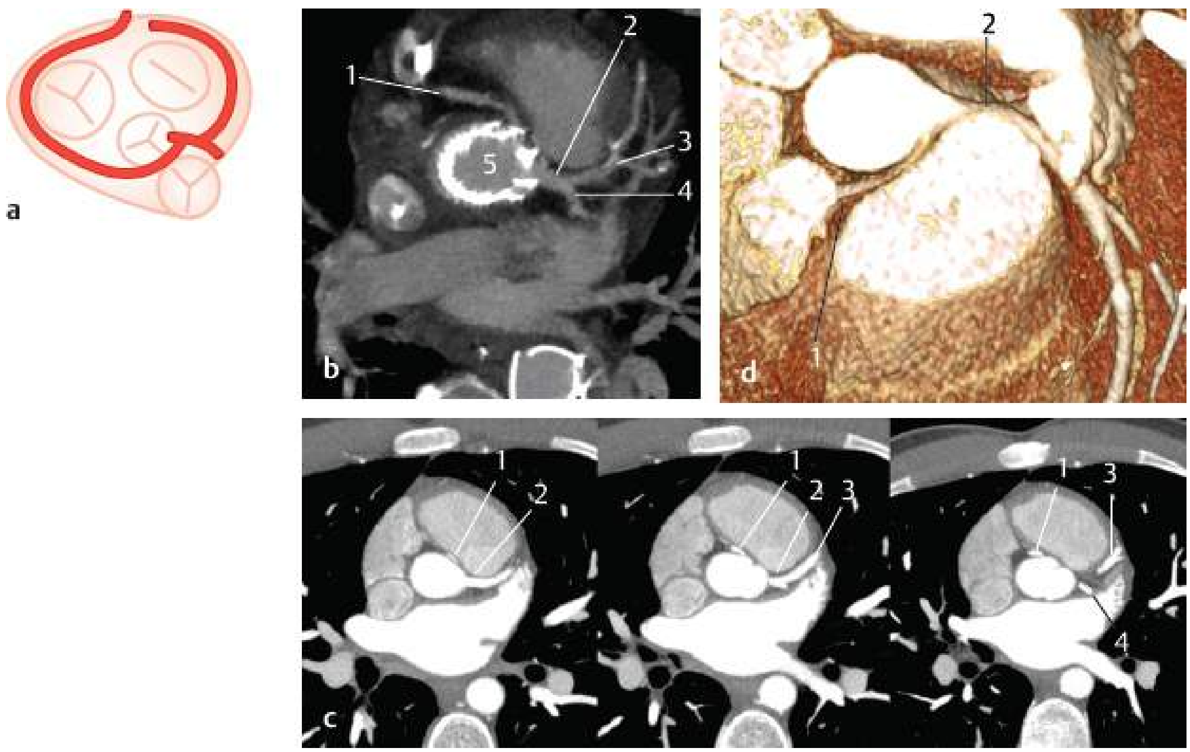

Fig. 3.10 Right coronary artery branches from the left coronary artery (<0.1%). Schematic (**a**) and coronary CTA of two patients (**b-d**). ***Patient 1***: MIP in oblique transverse view of the origin of the coronary arteries (**b**). Note the course of the right coronary artery between the pulmonary trunk and the ascending aorta. Patient status post replacement of the ascending aorta and the aortic valve due to aortic dissection. ***Patient 2***: MIPs in oblique transverse view of the origin of the coronary arteries (**c**), and VR 3D image cut at the level of the aortic root, superior view (**d**). **1** Right coronary artery; **2** left coronary artery; **3** anterior interventricular branch; **4** circumflex branch; **5** aorta.

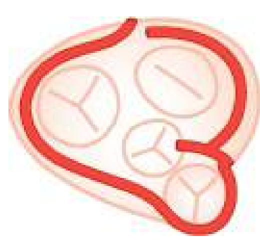

Fig. 3.11 Right coronary artery arises from the anterior interventricular branch (<0.1%). Schematic.

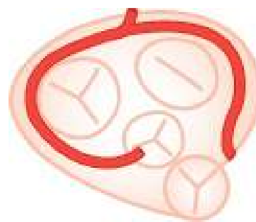

Fig. 3.12 Left coronary artery is absent, the heart is supplied by an extension of the right coronary artery (<0.1%). Schematic.

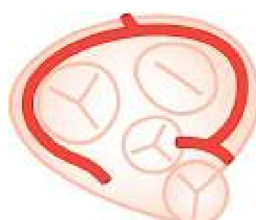

Fig. 3.13 Right coronary artery is absent, the left flex branch is extended and supplies the area of the right coronary artery (<0.1%). Schematic.

3.4 Origin from the Pulmonary Trunk (1%)

All six anlagen of valves in the outflow tract can have orifices for coronary arteries, thus explaining the origin of coronary arteries from the pulmonary trunk.[12,42] The left coronary artery originates from the pulmonary trunk (anomalous origin of the left coronary artery from the pulmonary artery or Bland-White-Garland syndrome), approximately 10 times more often than the right. This can be explained by the fact that the left orifice is located nearer to the pulmonary trunk.[11,12,23,43–59] The anomalous coronary artery often anastomoses with the normal one and, due to pressure differences, blood is shunted from the normal via the anomalous coronary artery into the pulmonary trunk. Consequently, the afflicted patient does not suffer from low oxygen tension but rather from perfusion pressure in the anomalous coronary artery. In very rare cases, coronary arteries can also arise from pulmonary arteries. A few cases have been described in which the coronary artery originated from the brachiocephalic trunk[60–62] or the bronchial arteries.[60,62,63]

Fig. 3.14 Accessory branch from the pulmonary trunk (<1%). Schematic.

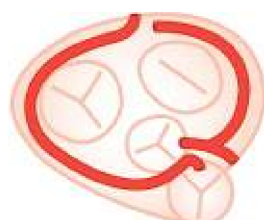

Fig. 3.15 Right coronary artery from the pulmonary trunk (<0.1%). Schematic.

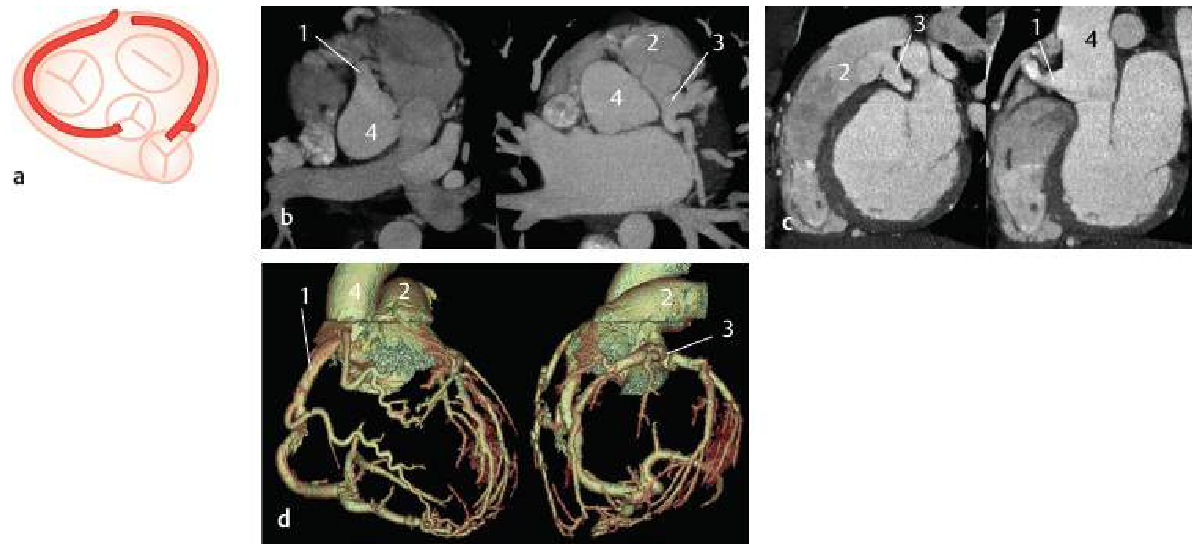

Fig. 3.16 Left coronary artery from the pulmonary trunk (<0.1%). Schematic (**a**) and coronary CTA of a 9-year-old patient with Bland–White–Garland syndrome (**b–d**). MIPs in oblique transverse (**b**) and oblique sagittal (**c**) views at the origin of the right coronary artery from the aorta and the left coronary artery from the pulmonary trunk, and VR 3D images (**d**) of the coronary arteries. **1** Right coronary artery; **2** pulmonary trunk; **3** left coronary artery; **4** aorta.

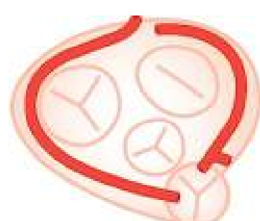

Fig. 3.17 Both coronary arteries from the pulmonary trunk (<0.1%). Schematic.

3.5 Anomalies of the Posterior Interventricular Branch

Normally, the posterior interventricular artery is a branch of the “normal type” of right coronary artery. If, however, it aries from the left coronary artery, the whole septum is supplied by the left coronary artery (“left type”). The other alternative is the “right type,” in which the right coronary artery reaches the parts of the heart beyond the posterior interventricular sulcus. In many cases, the anterior interventricular branch does not end at the apex of the heart, but reaches the posterior parts, resulting in two posterior interventricular branches—one from the cranial and the other from the caudal direction.[64–66]

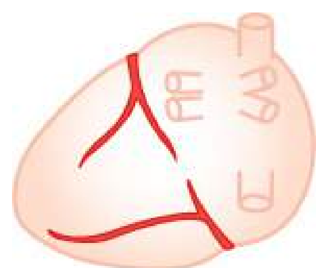

Fig. 3.18 “Normal” type: the posterior interventricular branch is the terminal branch of the right coronary artery (70%). Schematic.

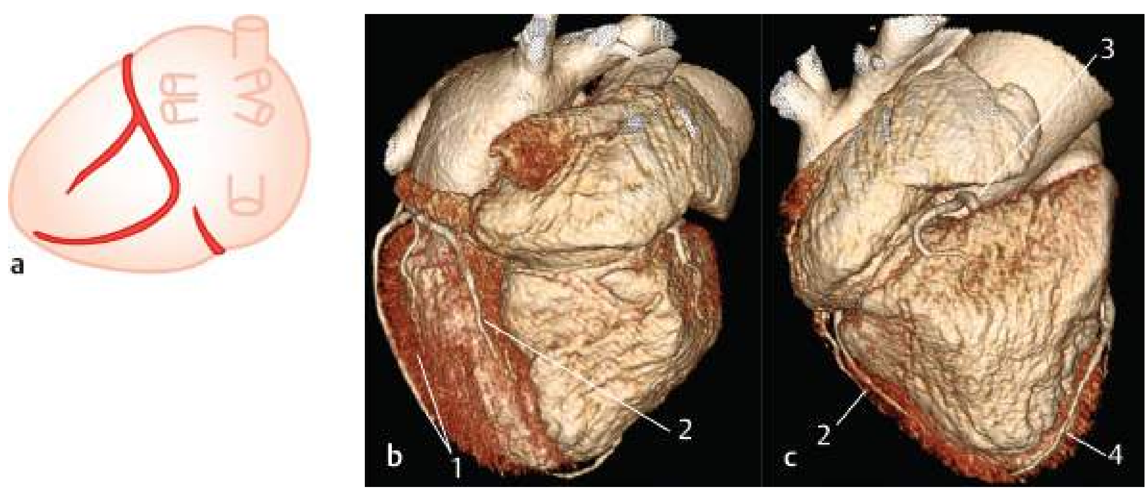

Fig. 3.19 “Left type” of blood supply: the posterior interventricular branch is the terminal branch of the left circumflex branch (20%). Schematic (**a**) and coronary CTA (**b,c**). VR 3D images in posterior (**b**) and lateral (**c**) views. **1** Posterior lateral branch of circumflex artery; **2** posterior interventricular branch of

circumflex artery; **3** right coronary artery; **4** anterior interventricular branch.

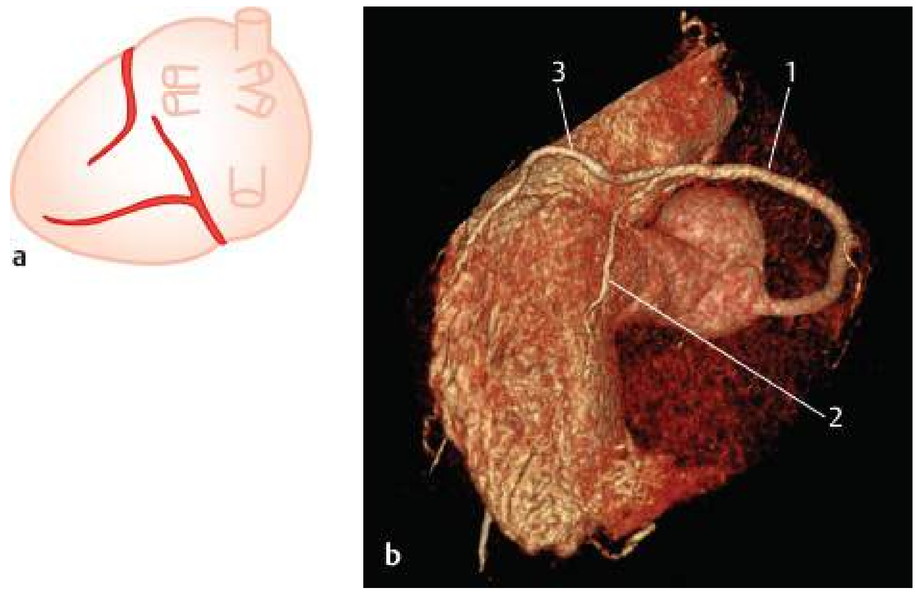

Fig. 3.20 “Right” type of blood supply: the right coronary artery supplies parts on the left side of the posterior interventricular sulcus (10%). Schematic (**a**) and coronary CTA (**b**). VR 3D image in posterior-inferior view. **1** Right coronary artery; **2** posterior interventricular branch; **3** right posterior lateral branch.

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4 Posterior Intercostal Arteries

D. Hortung, K. Hueper

The posterior intercostal arteries III to XI, the subcostal artery, and the lumbar arteries remain segmental posterior branches of the descending aorta.[1,2] When the heart descends, it causes the more cranial intercostal arteries to take an upward course. Their origins are therefore near to each other, explaining the occurrence of trunk formations of two or more arteries, especially of the third and fourth arteries. During embryologic development, a longitudinal anastomosis is formed between the segmental arteries C7, T1, and T2 and the original connections to the aorta disappear, resulting in the costocervical trunk. As a rule the anastomosis runs anterior to the ribs, but sometimes it is positioned between the rib and the transverse process, like the vertebral artery, which runs through the transverse foramina in the cervical vertebral column.[1–6]

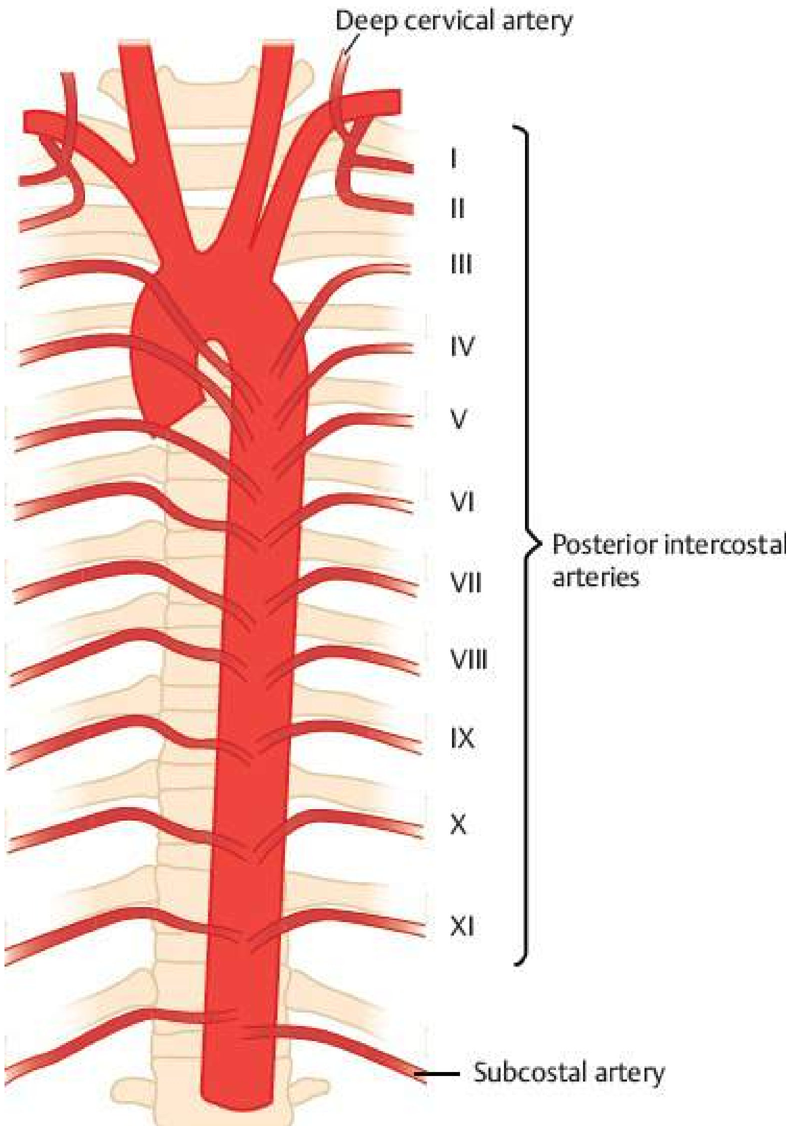

Fig. 4.1 “Normal” situation as given in textbooks. Schematic I–XI, posterior intercostal arteries.

4.1 Posterior Intercostal Arteries III–IX and Subcostal Artery

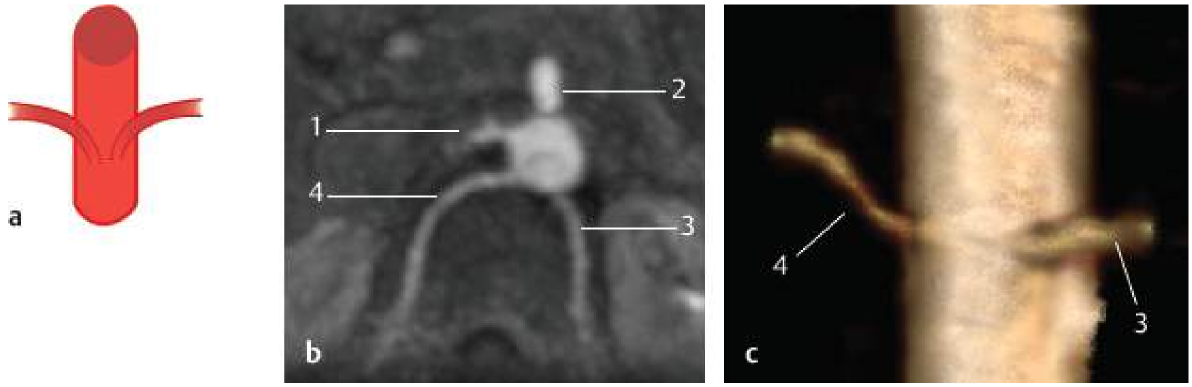

Fig. 4.2 Separate origins of the intercostal arteries of one segment (83%). Schematic (**a**) and MRA (**b,c**). MIP, transverse view (**b**) and VR 3D image, posterior view (**c**). **1** Right renal artery; **2** celiac trunk; **3** left intercostal artery; **4** right intercostal artery.

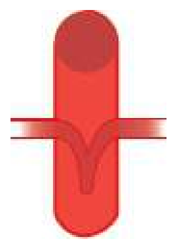

Fig. 4.3 Trunk formation of the intercostal arteries of one segment (2%). Schematic.

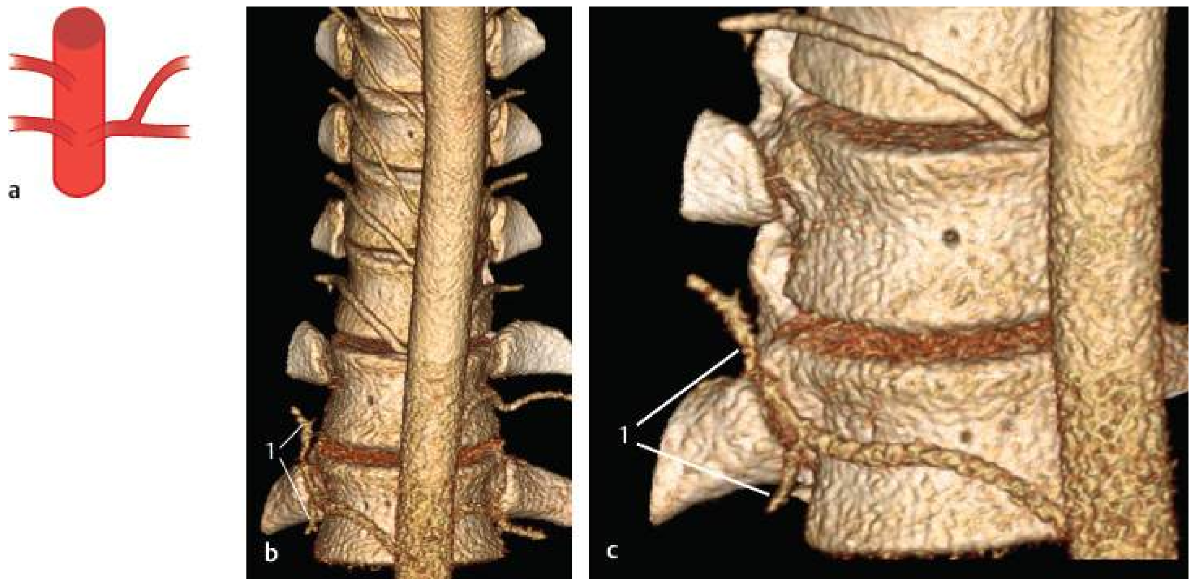

Fig. 4.4 Two intercostal arteries on one side arise from a trunk (13%). Schematic (**a**) and CTA (**b,c**). VR 3D images in anterior (**b**) and oblique lateral (**c**) view. The percentage is the mean of all segments. **1** Two right intercostal arteries on one side arising from a trunk.

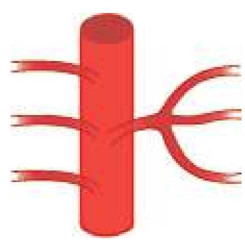

Fig. 4.5 Three or more intercostal arteries on one side arise from a trunk (2%). Schematic. The percentage is the mean of all segments.

4.2 The Supreme Intercostal Artery

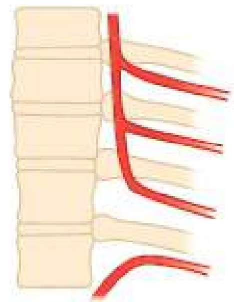

Fig. 4.6 The upper three intercostal arteries (I–III) originate via the supreme intercostal artery from the costocervical trunk of the subclavian artery (5%). Schematic.

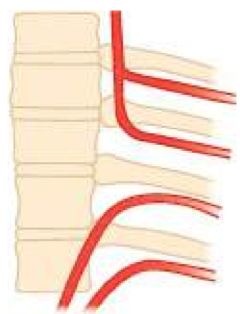

Fig. 4.7 Only the intercostal arteries I and II originate from the supreme intercostal artery (60%). Schematic.

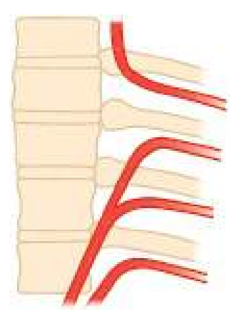

Fig. 4.8 Only the first intercostal artery is a branch of the costocervical trunk (32%). The second intercostal artery arises directly from the aorta; in approximately 50% of all cases it arises from a common trunk with the third intercostal artery. Schematic.

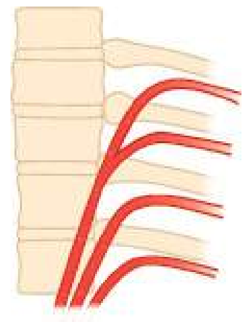

Fig. 4.9 The posterior intercostal arteries I and II are direct branches of the aorta (3%). Sometimes these two arteries form a trunk with the third intercostal artery. Schematic.

4.3 The Intercostal Arteries Run Posterior to the Ribs ("Thoracic Vertebral Artery")

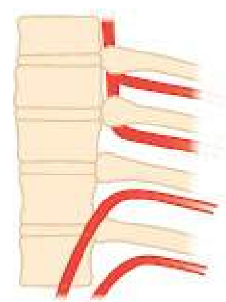

Fig. 4.10 Only the supreme intercostal artery lies in a posterior position (5%). Schematic.

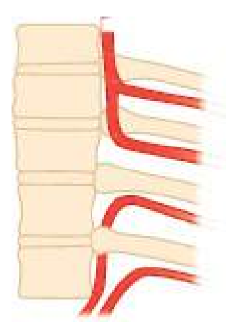

Fig. 4.11 Posterior position of the third intercostal artery (4%). Schematic.

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5 Esophageal Arteries

D. Hortung, K. Hueper

The esophageal arteries form a longitudinal anastomotic chain in contrast to the radial pattern of arteries in the intestines.[1–5] The esophagus can be divided into three segments.

5.1 Basic Pattern of Blood Supply to the Esophagus

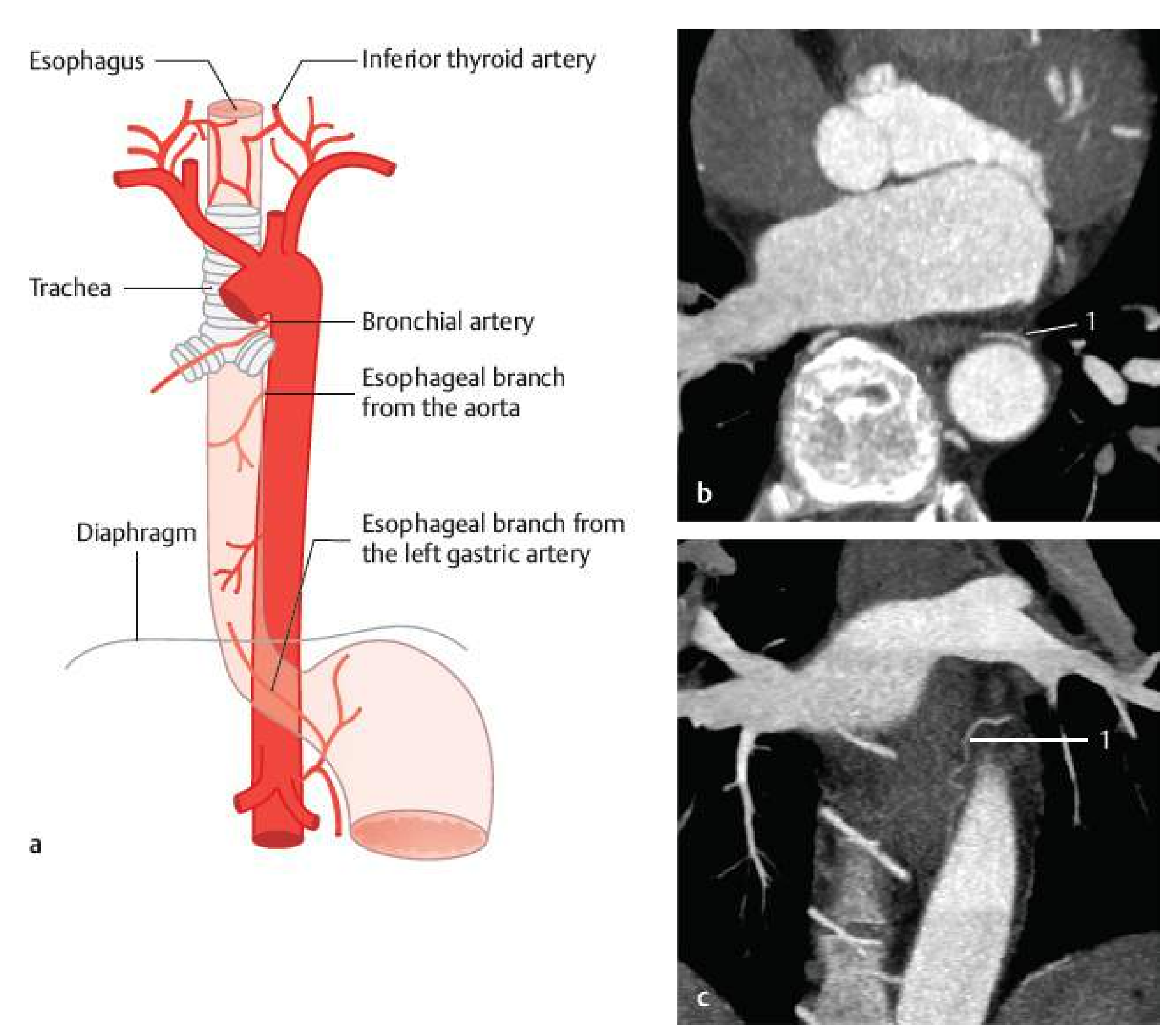

Fig. 5.1 Basic pattern of blood supply to the esophagus. Schematic (**a**) and CT (**b,c**). MIPs in transverse (**b**) and coronal (**c**) view. **1** Esophageal branch from the aorta.

5.2 Cervical Part of the Esophagus

The cervical part is usually supplied by the inferior thyroid artery, with more branches from the right than the left side. Other origins of arteries to the cervical part arise from the subclavian artery, the arteria thyroidea ima, or the common carotid artery.[4–6] Accessory arteries also come from these arteries.

Fig. 5.2 Branches from the inferior thyroid artery (68%). Schematic.

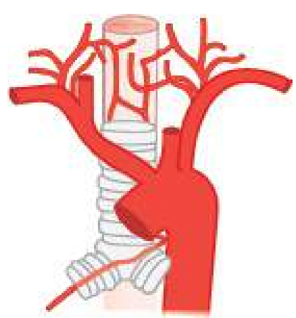

Fig. 5.3 Accessory branches from the subclavian artery (20%). Schematic.

Fig. 5.4 Accessory branches from the carotid artery (8%). Schematic.

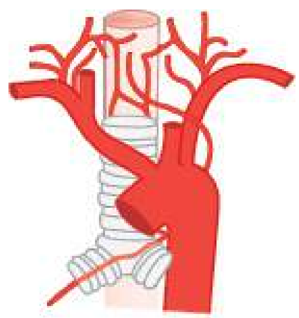

Fig. 5.5 Accessory branches from the aorta (8%). Schematic.

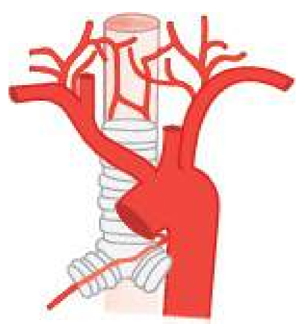

Fig. 5.6 Accessory branches from the vertebral artery (2%). Schematic.

5.3 Thoracic Part of the Esophagus

The portion adjacent to the bifurcation of the trachea is supplied by the bronchial arteries, more from the left than the right side. In addition, the third and fourth intercostal arteries give off branches. This results in only three esophageal branches, contrary to the information given in textbooks, which often refer to more.[1,4,5]

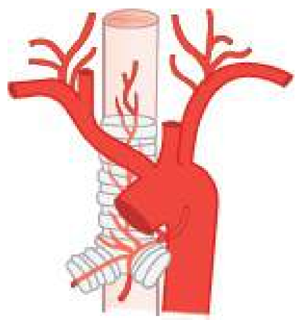

Fig. 5.7 Branches from the bronchial arteries, two on the left, one on the right (95%). Schematic.

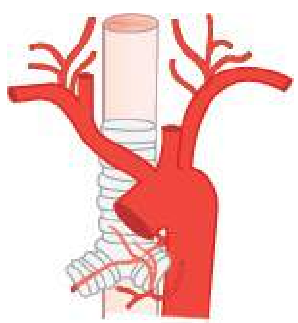

Fig. 5.8 Direct branches from the aorta as accessory arteries (5%). Schematic.

5.4 Abdominal P art of the Esophagus

The abdominal part of the esophagus is supplied by two to three branches from the left gastric artery. Other origins are the left accessory hepatic arteries and the left inferior phrenic artery.[1,4,5] Many esophageal arteries are relatively short, an important point to consider during surgical mobilization of the esophagus.[4]

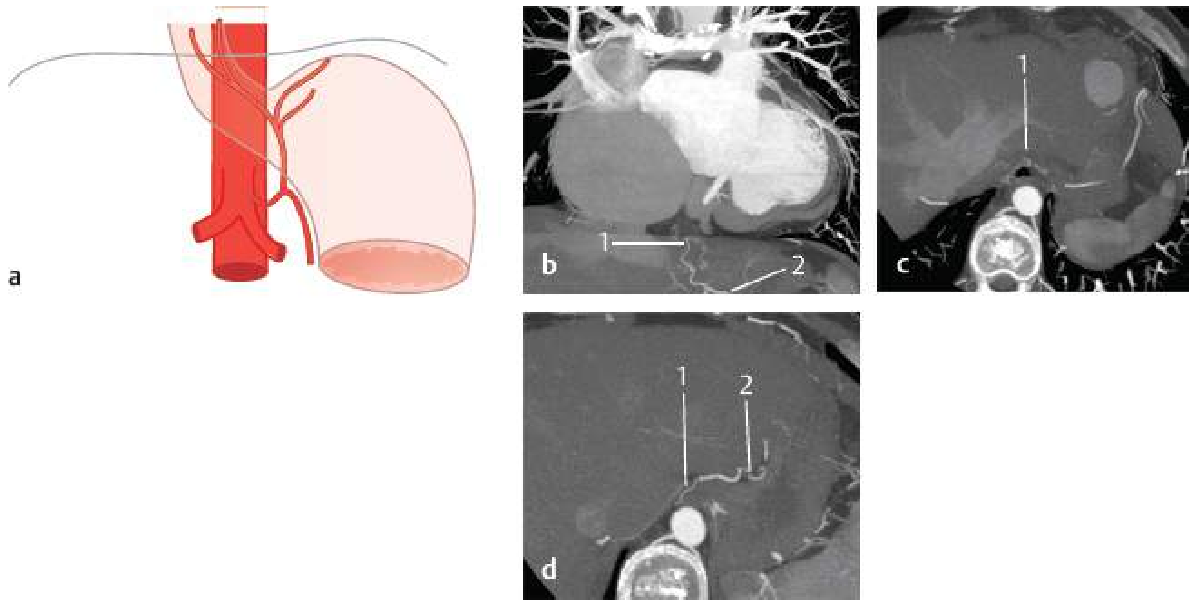

Fig. 5.9 Major arteries arise from the left gastric artery (90%). Schematic (**a**) and CT (**b–d**). MIPs in coronal (**b**), and transverse (**c,d**) view. **1** Esophageal artery; **2** left gastric artery.

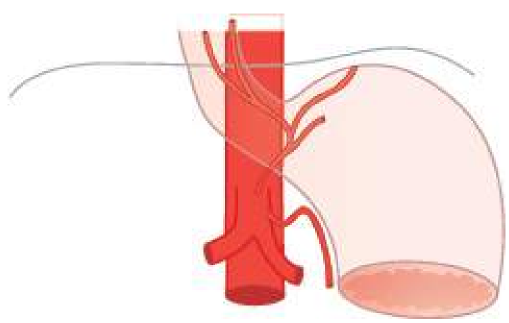

Fig. 5.10 Major arteries arise from the inferior phrenic artery (55%). Schematic.

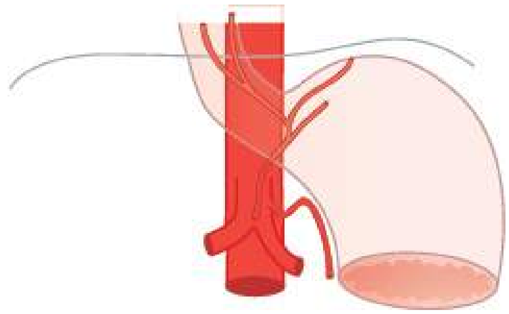

Fig. 5.11 Major arteries arise from the celiac trunk (16%). Schematic.

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6 Bronchial Arteries (Rami Bronchiales)

D. Hortung, K. Hueper

The bronchial arteries vary in origin, number, and size. They originate directly from the descending thoracic aorta, most commonly between the levels of the T5 and T6 vertebrae. [1–19] They supply the trachea, larger bronchi, and the bronchopulmonary lymph nodes. There are some anastomoses to the pulmonary arteries.[1,9,20] The anomalies fall within three categories:

– Whereas two bronchial arteries are usually present on the left side, the right side has only one.
– The bronchial arteries arise from the intercostal arteries on the right side and directly from the aorta on the left side.
– The right bronchial branches more often run posterior than anterior to the esophagus.

In rare instances, the bronchial arteries originate from the internal thoracic artery (**Fig. 6.7**), subclavian artery, supreme intercostal artery, inferior thyroid artery, ascending aorta, abdominal aorta, or the inferior phrenic artery.[1,2,8,21,22] Coronary to bronchial anastomoses can result in a coronary steal syndrome.[23] Spinal arteries may be seen at angiography during bronchial artery embolization for hemoptysis and embolization can rarely result in spinal cord ischemia.[24]

6.1 Bronchial Arteries—Topographic Anatomy

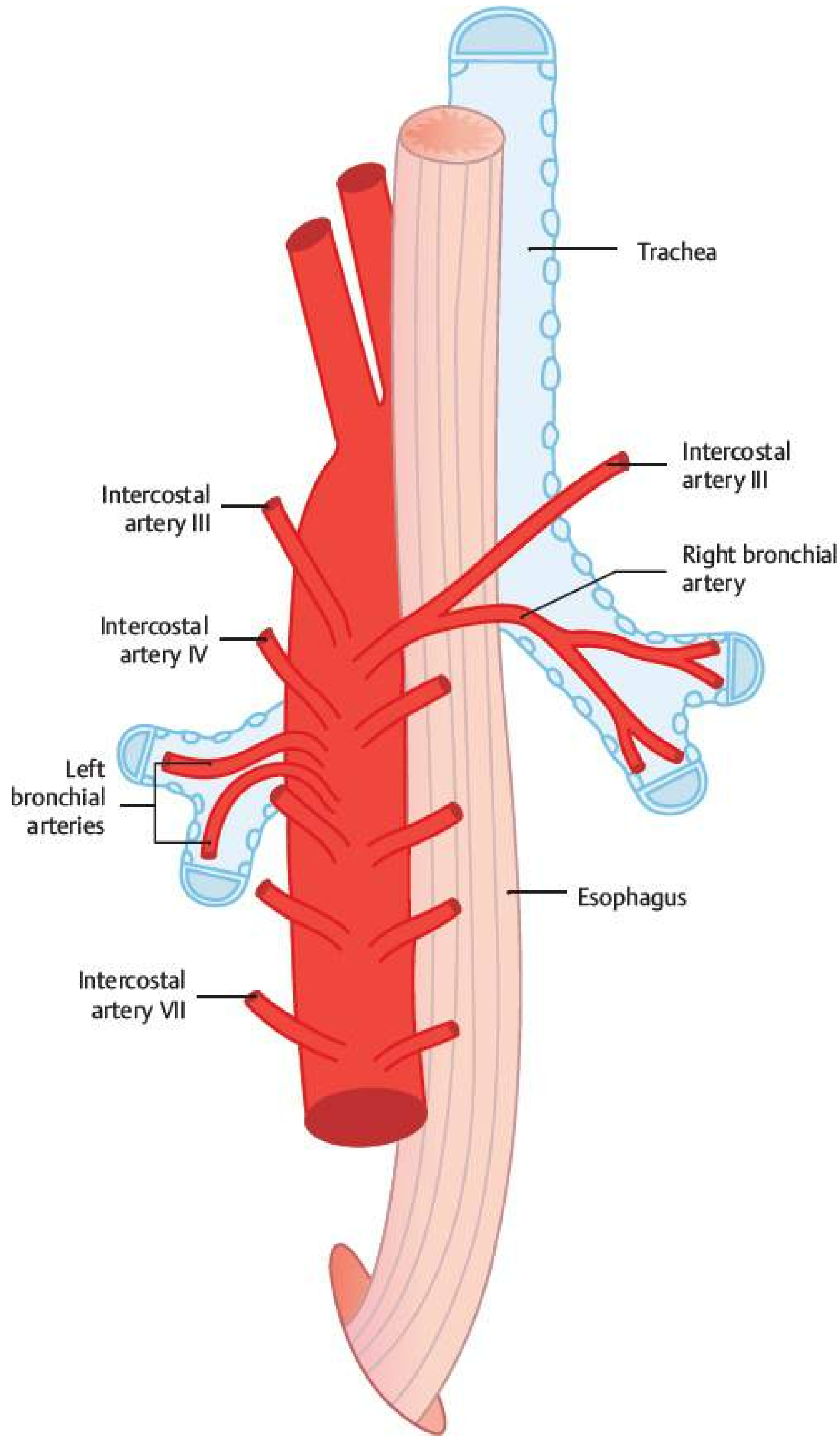
Trachea
Intercostal
artery III
Intercostal
artery III
Right bronchial
artery
Intercostal
artery IV
Left
bronchial
arteries
Esophagus
Intercostal
artery VII

Fig. 6.1 Topographic anatomy of the bronchial arteries. Schematic (corresponds to Fig. 6.4a).

6.2 Two Bronchial Branches (38%)

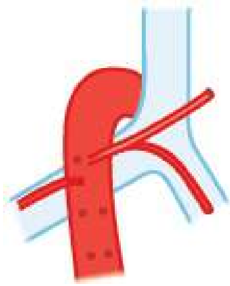

Fig. 6.2 Right bronchial branch from the third posterior intercostal artery (more seldom fourth or fifth); left bronchial branch directly from the aorta (31%). Schematic.

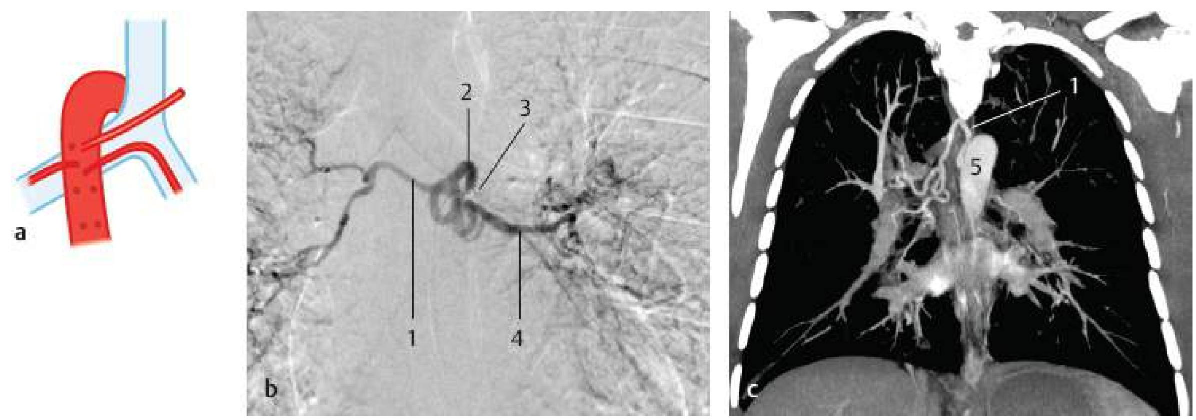

Fig. 6.3 Both branches directly from the aorta, sometimes with a common trunk (7%). Schematic (**a**); DSA of the bronchial arteries with the catheter in the ostium of the common trunk of both bronchial branches, anterior view (**b**); and CT, MIP in the coronal plane; prominent right bronchial artery directly from the aorta (**c**). **1** Right bronchial artery; **2** common trunk; **3** angiography catheter in the common trunk; **4** left bronchial artery; **5** descending aorta.

6.3 Three Bronchial Branches (44%)

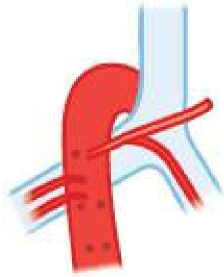

Fig. 6.4 Two left bronchial arteries (39%). The two left arteries originate mostly from the aorta, less frequently from the right posterior intercostal artery III or IV. Schematic.

Fig. 6.5 Two right bronchial arteries (5%). Schematic (**a**); ectopic right bronchial artery from the aortic arch as one of two right bronchial arteries; angiography (**b**); and DSA with the catheter in the ostium (**c**). **1** Right bronchial artery originating from the aortic arch.

6.4 Four Bronchial Branches (16%)

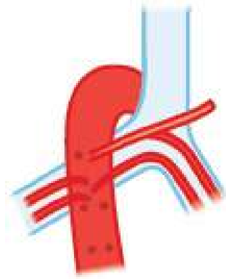

Fig. 6.6 Two right and two left bronchial branches (12%). Schematic.

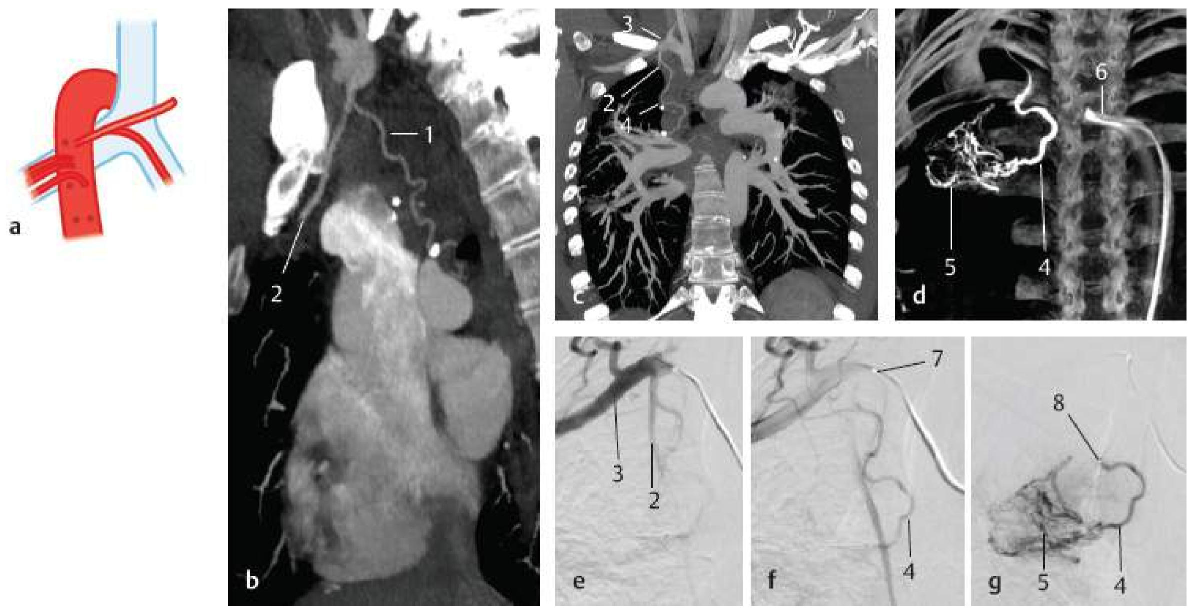

Fig. 6.7 Two right bronchial arteries (4%). Schematic (**a**). MIP CT images in sagittal (**b**) and coronal (**c**) views showing an ectopic right bronchial branch originating as one of two bronchial arteries from the right internal thoracic artery in a patient with aspergilloma and bleeding. Angiographic C-arm CT with the catheter in the ectopic right bronchial branch (**d**). DSA with the catheter in the subclavian artery showing the origin of the bronchial branch from the internal thoracic artery (**e**). DSA after selective injection into the bronchial branch with bleeding (**f**). **1** Right bronchial branch; **2** internal thoracic artery; **3** subclavian artery; **4** bronchial branch; **5** bleeding from bronchial arteries; **6** angiography catheter; **7** catheter; **8** tip of the microcatheter.

6.5 Five or More Bronchial Branches (<2%)

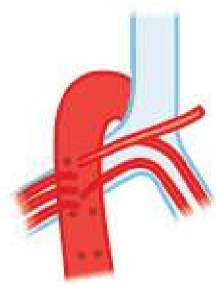

Fig. 6.8 Two right and three or more left bronchial branches (1%). Schematic.

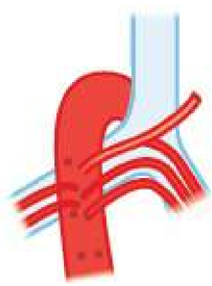

Fig. 6.9 Three right and two or more left bronchial branches (<1%). Schematic.

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7 Pulmonary Arteries

D. Hortung, K. Hueper

Since anomalies of the pulmonary trunk or the pulmonary arteries are normally combined with heart defects or a patent ductus arteriosus (Botallo's duct), they are more aptly classified as malformations. Many anomalies can be explained on the basis of embryological development of the aortic arches (Chapter 2). They can be classified as a systemic arterial blood supply to the lung, an atypical course of a pulmonary artery (sling formation), and the absence of one pulmonary artery.

The pulmonary arteries derive from the sixth aortic arch (Chapter 2). Whereas its distal part, the connection with the posterior aorta, disappears, it remains open on the left side until birth as the ductus arteriosus. Many anomalies can be attributed to the failure of an arch to develop normally or to a precipitous regression or a sudden hiatus of growth. [1–7]

7.1 Normal Situation and Development

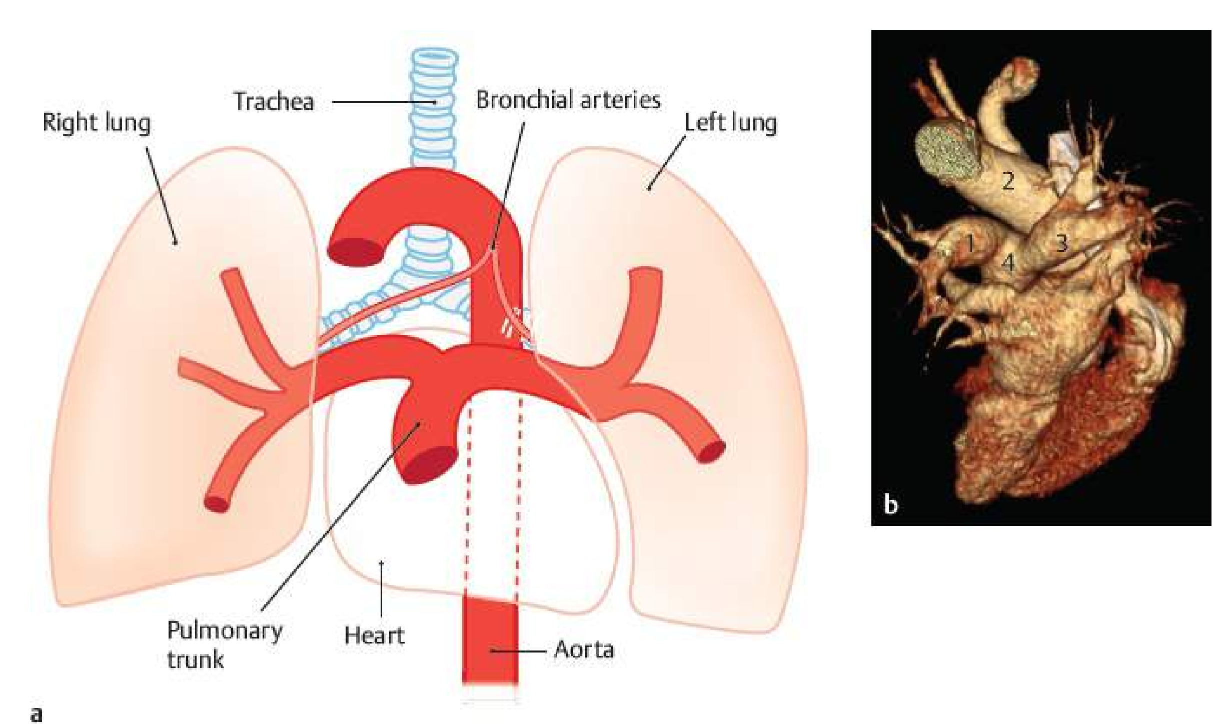

Fig. 7.1 Normal blood supply to the lung (>99%). Schematic (**a**) and contrast-enhanced CT (**b**). VR 3D image, oblique posterior view. **1** Left pulmonary artery; **2** aorta; **3** right pulmonary artery; **4** pulmonary trunk.

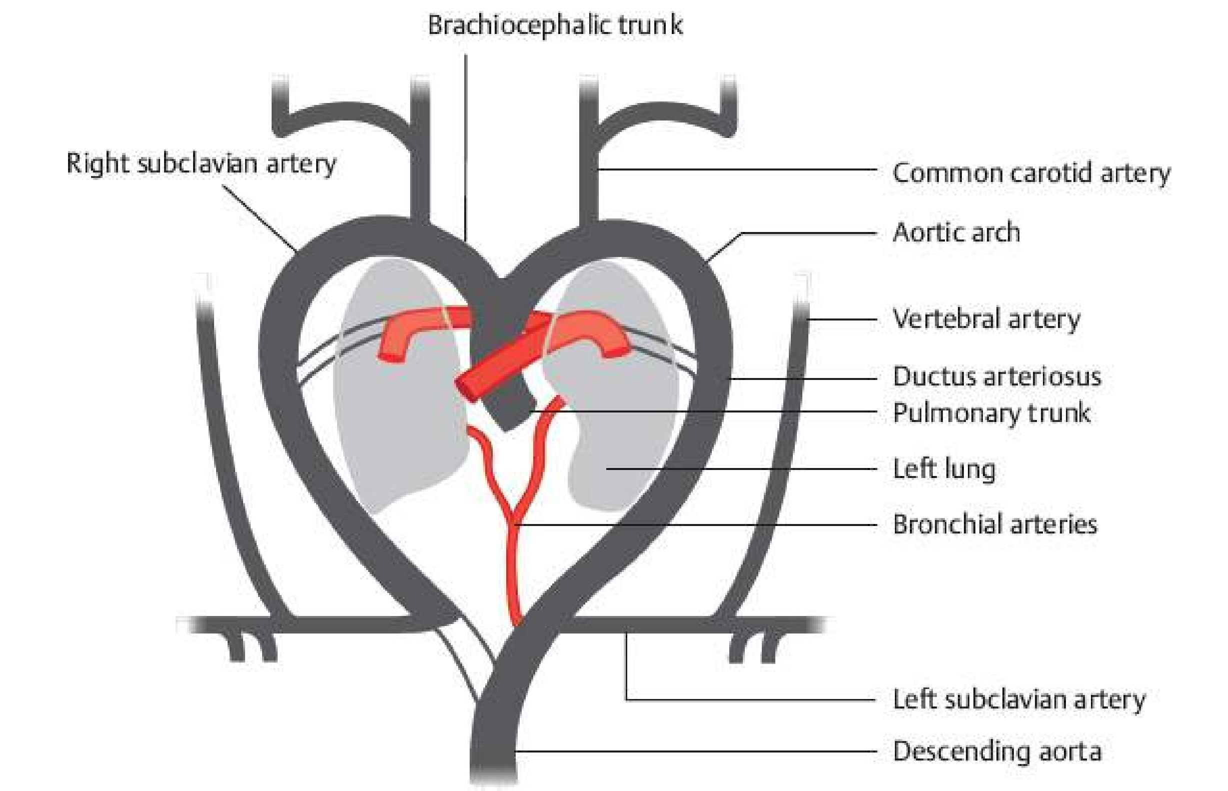

Fig. 7.2 Development of pulmonary arteries from sixth aortic arch. Schematic.

7.2 Supply by Systemic Arteries as Branches from the Aorta

An anomaly in which systemic arteries supply blood to the lung can be explained by the early stage of embryologie development during which branches of the posterior aortas are most often affected by this anomaly, which causes problems of higher systemic blood pressure and flow.[2,8–12]

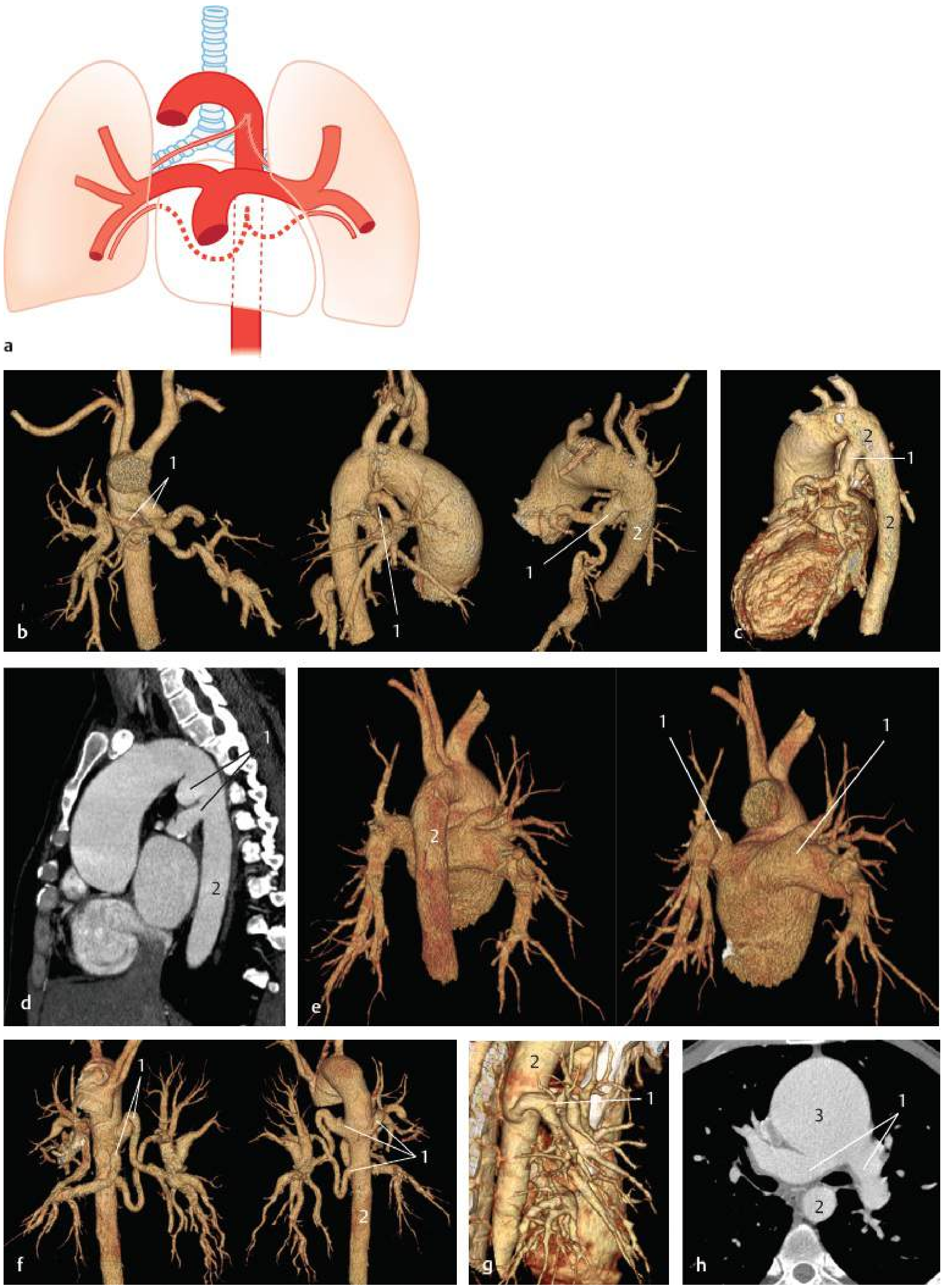

Fig. 7.3 Supply by systemic arteries as branches from the aorta

(**very rare**). Schematic (**a**) and contrast-enhanced CT of the thoracic aorta from three patients (**b–h**). ***Patient 1***: VR 3D images, posterior and lateral views (**b**), left lateral view (**c**), and MIP in sagittal view (**d**). ***Patient2***: VR 3D images, posterior view and posterior view with descending aorta removed (**e**). ***Patient 3***: VR 3D images, ventral and posterior views (**f**), right lateral oblique view (**g**), and MIP in transverse view (**h**). Major aortopulmonary collaterals are shown. **1** Pulmonary arteries; **2** descending aorta; **3** ascending aorta.

7.3 Sling Formation

Pulmonary slings are normally caused by an aberrant left pulmonary artery which arises from the right pulmonary artery and passes between the trachea and the esophagus to the left lung, producing respiratory distress. [13–18]

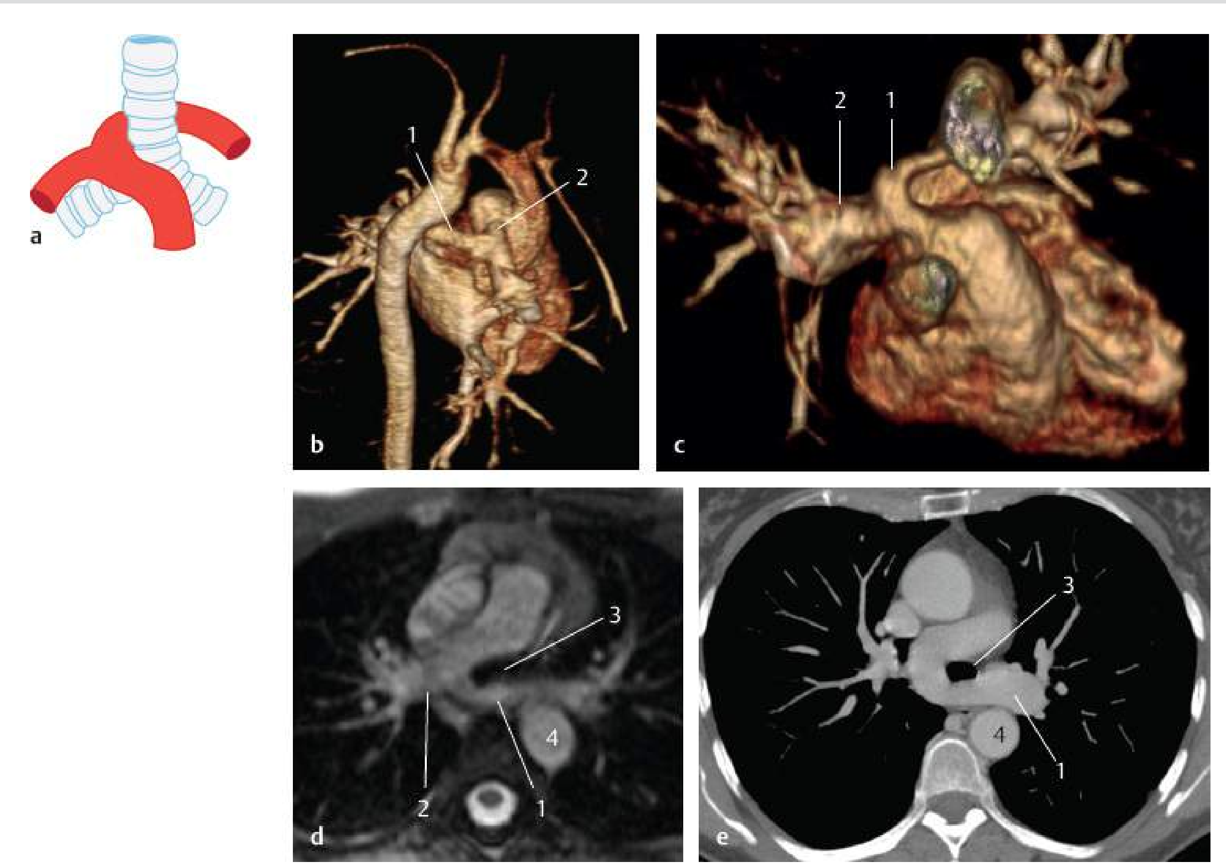

Fig. 7.4 Sling formation: aberrant left pulmonary artery from the right pulmonary artery passing between the trachea and the esophagus to the left (very rare). Schematic (**a**) and images from two patients (**b–e**). ***Patient 1***: MRA, VR 3D images, lateral oblique view (**b**), frontal oblique view (**c**), and multi-planar reformation in transverse view (**d**). ***Patient 2***: Contrast-enhanced CT; MIP in transverse view (**e**). **1** Left pulmonary artery; **2** right pulmonary artery;

3 trachea; **4** descending aorta.

7.4 Absence of One of the Pulmonary Arteries

If one pulmonary artery is absent, normally only its proximal part is missing. The more distal parenchymal vessels are generally small but intact.[1,2,5,19,20] In these cases, either the ductus arteriosus remains patent or a bronchial artery supplies blood to the affected lung.

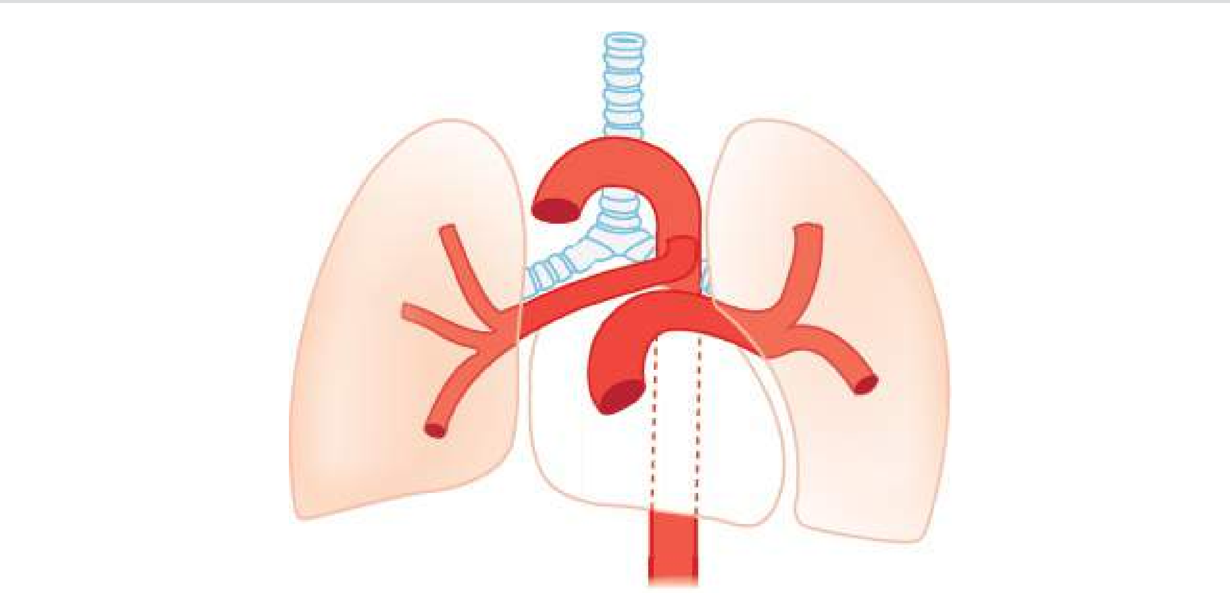

Fig. 7.5 Absence of the right pulmonary artery: enlarged bronchial arteries supply the lung (very rare). Schematic.

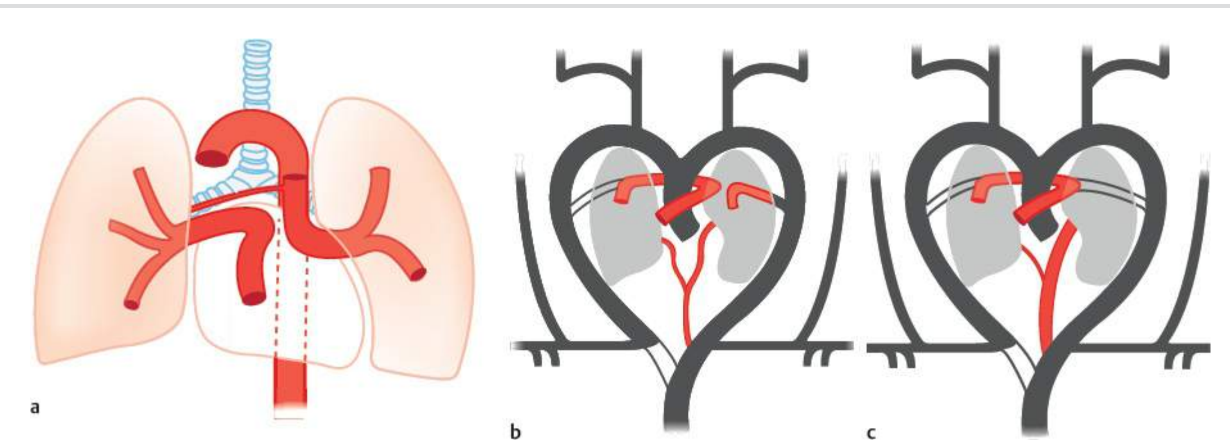

Fig. 7.6 Absence of the left pulmonary artery (very rare). Schematics showing the arterial variation (**a**) and its development (**b,c**). The ductus arteriosus remains patent (**b**). Enlarged bronchial arteries supply the lung (**c**).

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basilar segments of the left lower lobe. AJR Am J Roentgenol 1976;126(4):817–821

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Part II

Pelvis and Abdomen

8 Development of the Abdominal Aorta

K.I. Ringe, S. Meyer

The branches of the abdominal aorta may be divided into three groups: posterior, lateral, and anterior.

8.1 Posterior Branches

The posterior branches are segmental like the branches of the thoracic aorta.[1] The lumbar arteries I–IV remain segmental arteries, but the more important fifth artery forms the main artery for the leg, the common iliac artery. It is comparable to the main vessel supplying the arm, the subclavia, which develops from the sixth cervical segmental artery. Caudal to the fifth lumbar artery, the aorta regresses to the small median sacral artery. The lumbar arteries are not described in detail because their anomalies are comparable to those of the intercostal arteries (Chapter 4). Although the trunk formation of both lumbar arteries from one segment is more common (4%), the origin of two or more lumbar arteries on one side is much more seldom (2%) than in the thoracic region.[1]

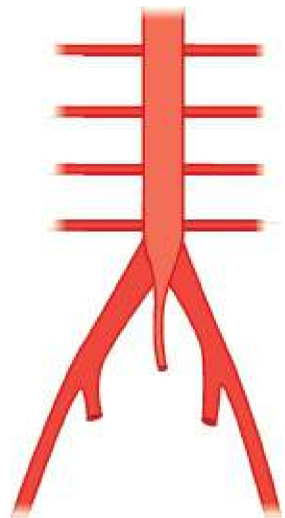

Fig. 8.1 Development of the posterior branches. Schematic.

8.2 Lateral Branches

The lateral branches supply the kidneys and the genital organs. The mesonephric arteries supply the mesonephros, the adrenal glands, and testicles or ovaries. In the second month of pregnancy the adrenal gland is much larger than the kidney and is supplied by three arteries: the superior, middle, and inferior suprarenal arteries. One branch runs from the superior suprarenal artery to the diaphragm and another from the inferior suprarenal artery to the kidney. Later the kidneys grow much faster than the adrenal glands; in the neonate, they are one-third of the kidney weight but in adults only 1/30. Consequently, the suprarenal arteries become less important, and their side branches regress into the main artery. The superior suprarenal artery becomes a small branch of the inferior phrenic artery and the inferior suprarenal artery, a comparably tiny branch of the renal artery. The testicles and ovaries descend, thus elongating their arteries. The origins of these arteries retain their site on the aorta.

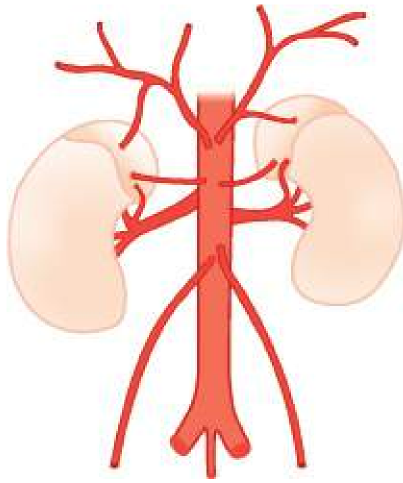

Fig. 8.2 Development of the lateral branches. Schematic.

8.3 Anterior Branches

The anterior branches develop initially as paired vessels. The arteries to the gut merge early to form the celiac trunk and the superior and inferior mesenteric arteries.[1–3] The umbilical arteries are also anterior branches which, however, are much larger than all other branches of the aorta in the embryo. The umbilical arteries remain paired vessels, but their origins vary. Longitudinal anastomoses to the segmental artery L5 develop and the initial aorta origins disappear. After birth these arteries are no longer necessary; their distal parts form the lateral umbilical ligaments.

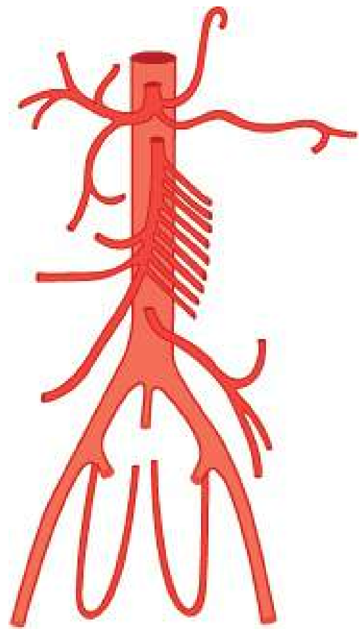

Fig. 8.3 Development of the anterior branches. Schematic.

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9 Inferior Phrenic Arteries

K.I. Ringe

These small arteries supply the diaphragm from the abdominal side. They anastomose with the small superior phrenic arteries, branches of the thoracic aorta, and the musculophrenic and the pericardiophrenic arteries, which are branches of the internal thoracic arteries. The inferior phrenic arteries stem from the mesonephric arteries and thus also supply the adrenal gland via the superior suprarenal artery. This embryologic development elucidates the rare origins of the inferior phrenic arteries from the renal, testicular, or ovarian arteries (**Fig. 9.7**, **Fig. 9.9**). Their origin from the celiac trunk (**Fig. 9.8**) has been found surprisingly often and can only be explained by a secondary transposition on account of the vessels' different growth rates. The normal pattern described in textbooks accounts for only about a quarter of all cases.[1–12]

9.1 Both Inferior Phrenic Arteries Originate from a Common Trunk (33%)

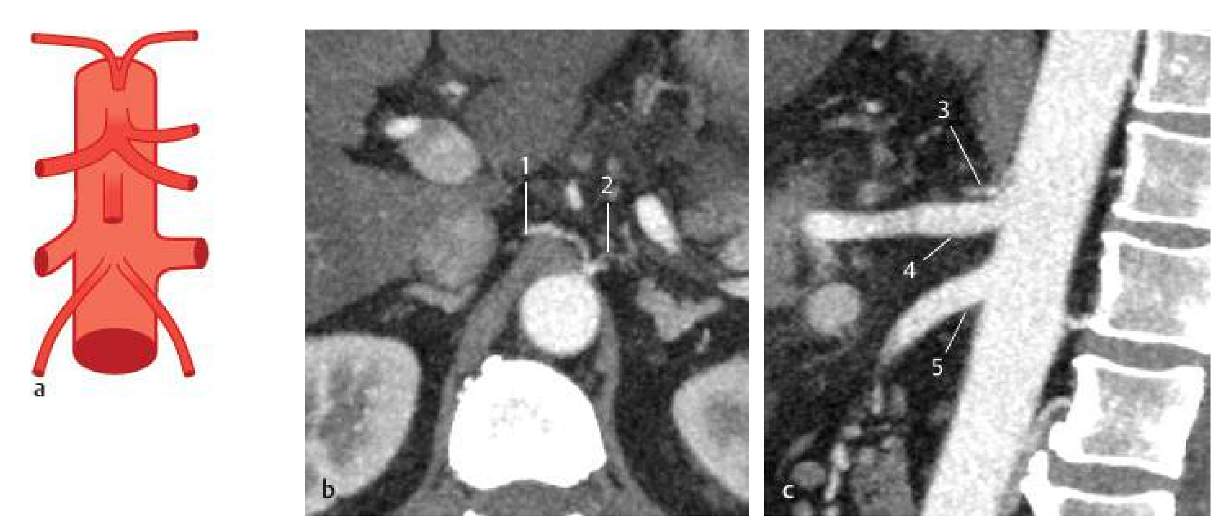

Fig. 9.1 Origin from the aorta just above the celiac trunk (18%). Schematic (**a**) and CT images (**b**,**c**). MIP, axial (**b**) and sagittal (**c**) views. **1** Right phrenic artery; **2** left phrenic artery; **3** common phrenic branch; **4** celiac trunk; **5** superior mesenteric artery.

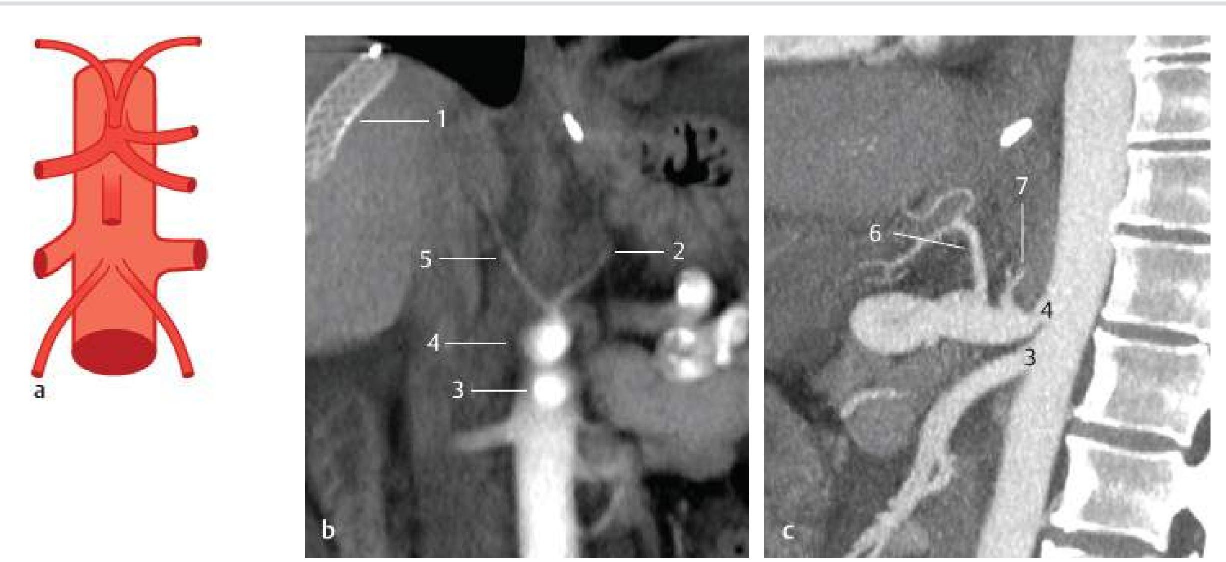

Fig. 9.2 Origin from the celiac trunk (14%). Schematic (**a**) and CT images (**b**,**c**). AvIP, coronal view (**b**); and MIP, sagittal view (**c**). A transjugular intrahepatic portosystemic shunt (TIPS) can be appreciated. **1** TIPS; **2** left phrenic artery; **3** superior mesenteric artery; **4** celiac trunk; **5** right phrenic artery; **6** common hepatic artery; **7** phrenic artery.

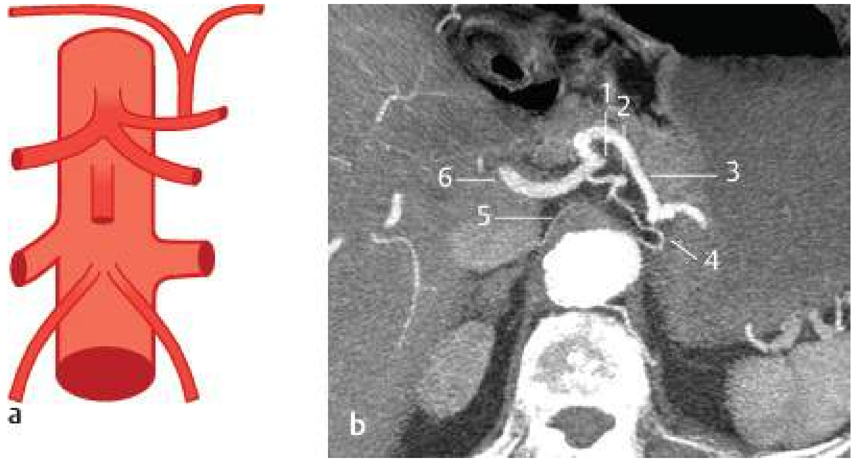

Fig. 9.3 Origin from the left gastric artery (1%). Schematic (**a**) and axial MIP CT at the level of the celiac trunk (**b**). **1** Celiac trunk; **2** left gastric artery; **3** splenic artery; **4** left phrenic artery; **5** right phrenic artery; **6** common hepatic artery.

9.2 The Inferior Phrenic Arteries Have Separate Origins (67%)

Fig. 9.4 Origin from the abdominal aorta (right side 29%; left side 24%). Schematic (**a**), axial MIP CT above the level of the celiac trunk (**b**), and coronal VR CT (**c**). In **c** an upper polar renal artery can be appreciated on the left (*). **1** Right phrenic artery; **2** left phrenic artery; **3** splenic artery; **4** celiac trunk; **5** superior mesenteric artery.

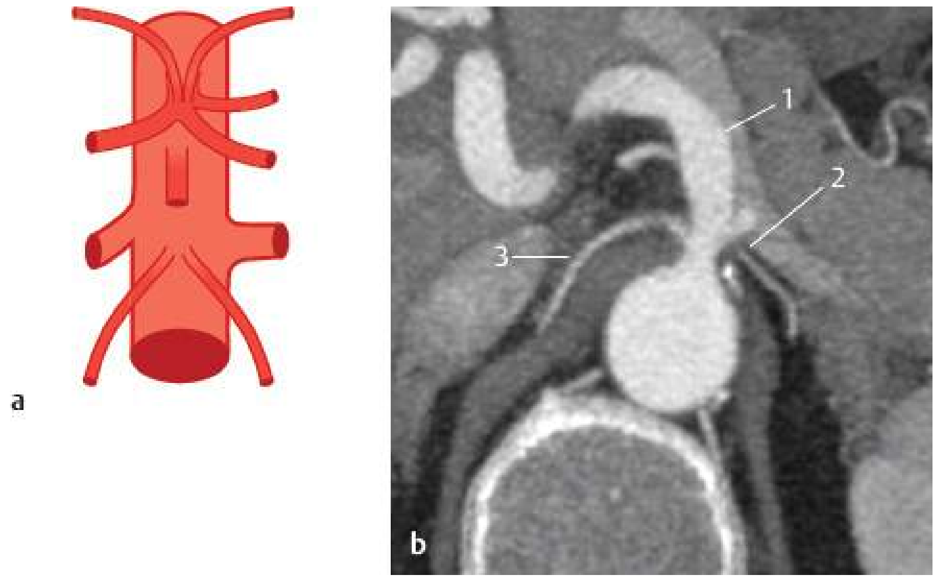

Fig. 9.5 Origin from the celiac trunk (right side 27%; left side 38%). Schematic (**a**) and axial MIP CT at the level of the celiac trunk (**b**). **1** Celiac trunk; **2** left phrenic artery; **3** right phrenic artery.

Fig. 9.6 Origin from the left gastric artery (right side 3%; left side 4%). Schematic (**a**) and reformatted CT above the level of the celiac trunk (**b,c**). Axial (**b**) and sagittal (**c**) views. The left gastric artery is replaced and arises directly from the aorta. **1** Right phrenic artery; **2** left gastric artery; **3** left phrenic artery; **4** Superior mesenteric artery; **5** celiac trunk.

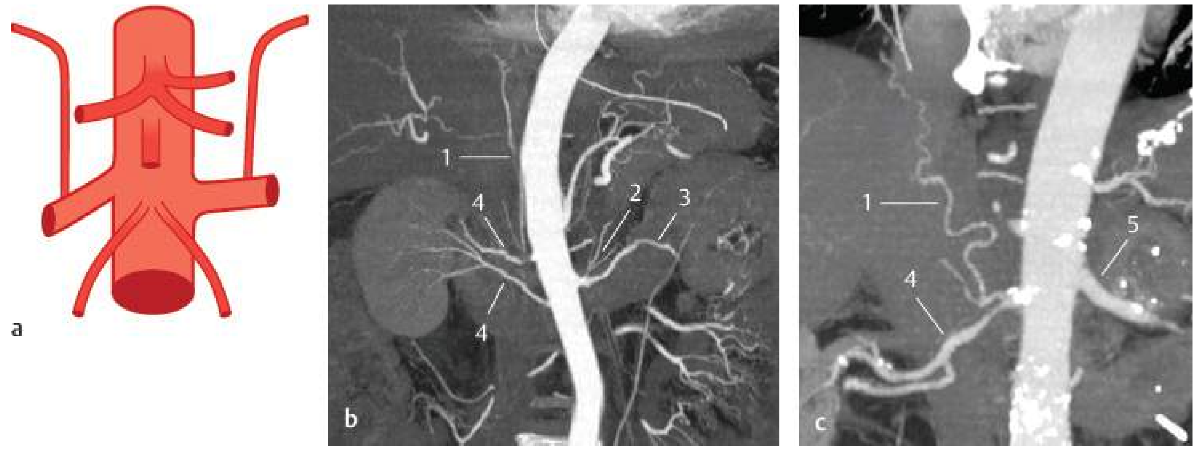

Fig. 9.7 Origin from the renal artery (right side 7%; left side <0.1%). Schematic (**a**) and CT images from two different patients (**b,c**). ***Patient 1***: Coronal MIP of the abdominal aorta with separate origins of the inferior phrenic arteries from the right and left renal arteries, respectively (**b**). On the right, two renal arteries can be appreciated. ***Patient 2***: Coronal oblique MIP CT of the abdominal aorta with the inferior phrenic arteries originating from the right renal artery (**c**). Patient status post nephrectomy on the left side; the left inferior phrenic artery cannot be appreciated. **1** Right phrenic artery; **2** left phrenic artery; **3** left renal artery; **4** right renal artery; **5** superior mesenteric artery.

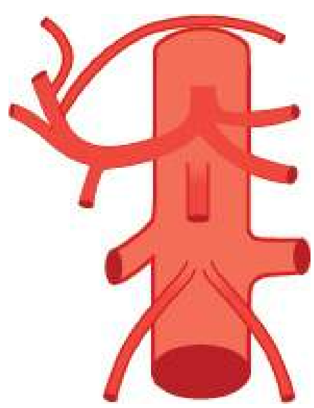

Fig. 9.8 Origin from the left hepatic artery (right side 1%; left side 1%). Schematic.

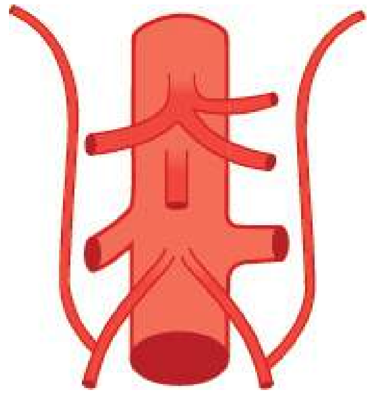

Fig. 9.9 Origin from the testicular or ovarian artery (right side <1%; left side <1%). Schematic.

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10 Suprarenal Arteries

K.I. Ringe, S. Meyer

The official anatomical nomenclature cites three arteries supplying the suprarenal gland:

– The superior suprarenal artery from the inferior phrenic artery.
– The middle suprarenal artery, a direct branch of the aorta.
– The inferior suprarenal artery, a branch from the renal artery.

However, careful preparations after dye injection or corrosion cast preparations give a much more complex picture. The suprarenal arteries are always multiple, and they branch before entering the gland. They could be compared with spokes of a wheel, the suprarenal gland serving as the hub. Up to 60 arterial branches have been counted to enter the gland.[1–9] The venous return, however, takes place via only one suprarenal vein; accessory veins are rarely found.

The inferior suprarenal arteries are in part derived directly from the renal arteries and in part from the renal capsule, which is supplied not only by the renal artery but also by branches from the testicular, ovarian, or lumbar arteries. Even a direct origin of the inferior suprarenal artery from the testicular and ovarian arteries has been described.[1–3,7,9]

10.1 Blood Supply from Three Different Origins (34%)

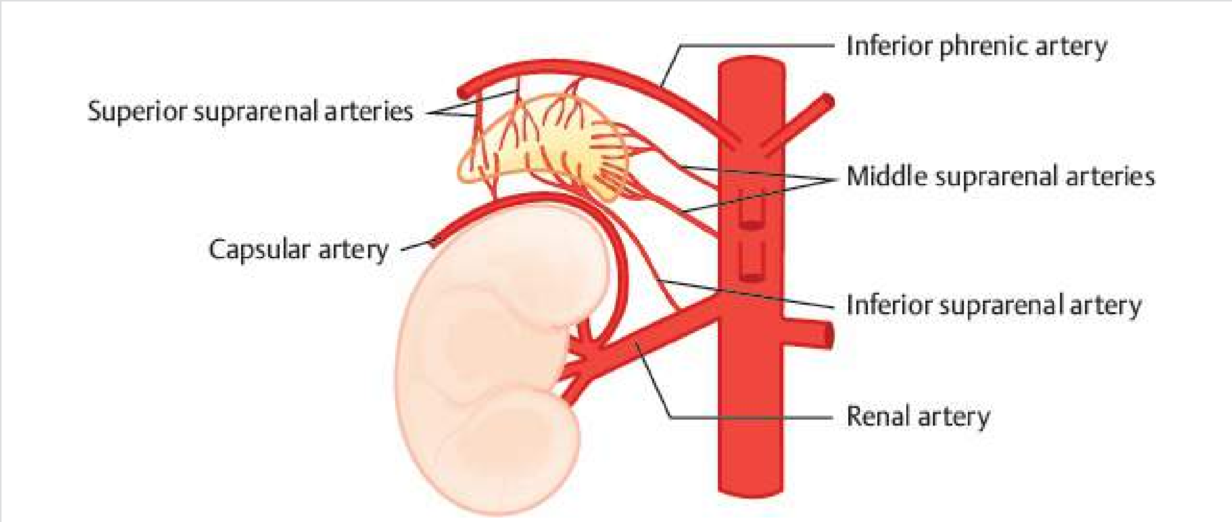

Fig. 10.1 Blood supply from three different origins (34%). Schematic.

10.2 Blood Supply from Two Different Origins (61%)

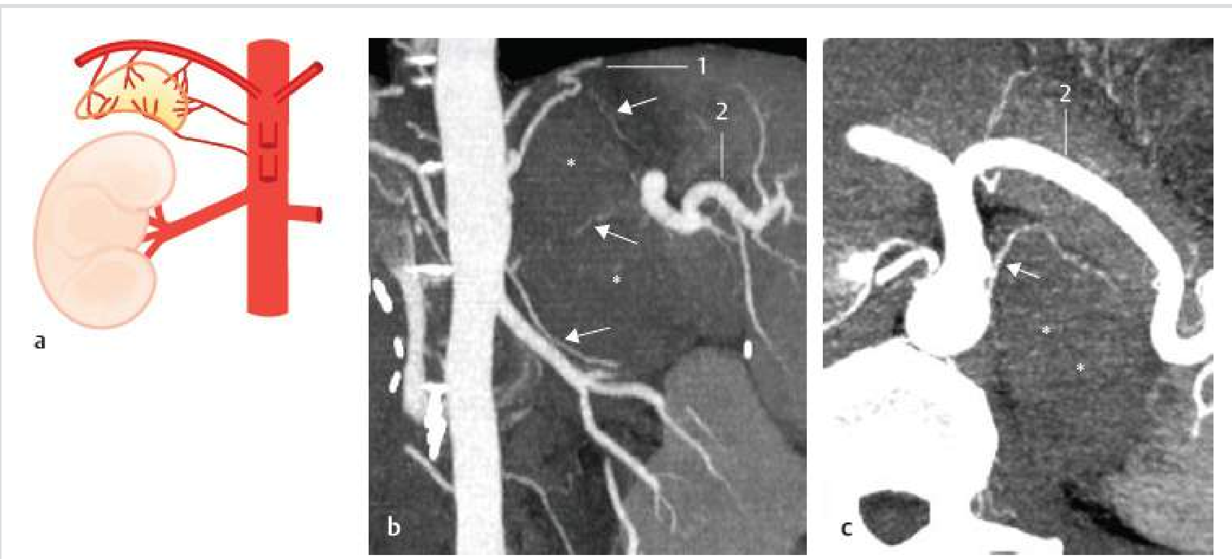

Fig. 10.2 From the inferior phrenic artery and the aorta (more often left than right) (26%). Schematic (**a**) and CT images (**b**,**c**) in a patient with a large adrenal mass on the left (*). MIP in coronal oblique (**b**) and axial (**c**) view. The suprarenal gland is supplied by branches (arrows) from the inferior phrenic artery and the aorta. **1** Left phrenic

artery; **2** splenic artery.

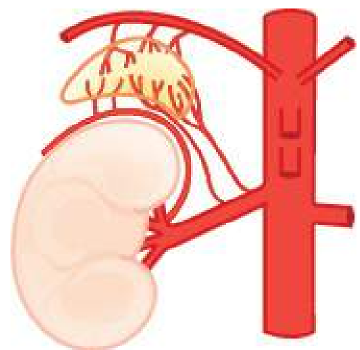

Fig. 10.3 From the inferior phrenic artery and the renal artery (more often right than left) (33%). Schematic.

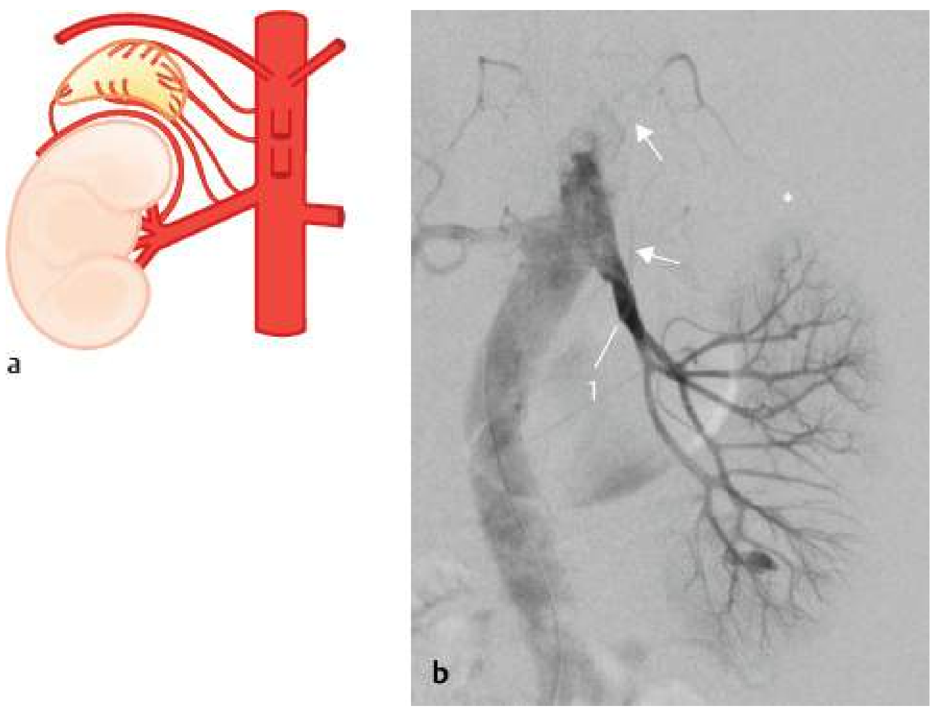

Fig. 10.4 From the aorta and the renal artery (2%). Schematic (**a**) and DSA with blood supply (arrow) of the left adrenal gland (*) from the aorta and the left renal artery (**b**). **1** Left renal artery.

10.3 Blood Supply from One Vessel Only (5%)

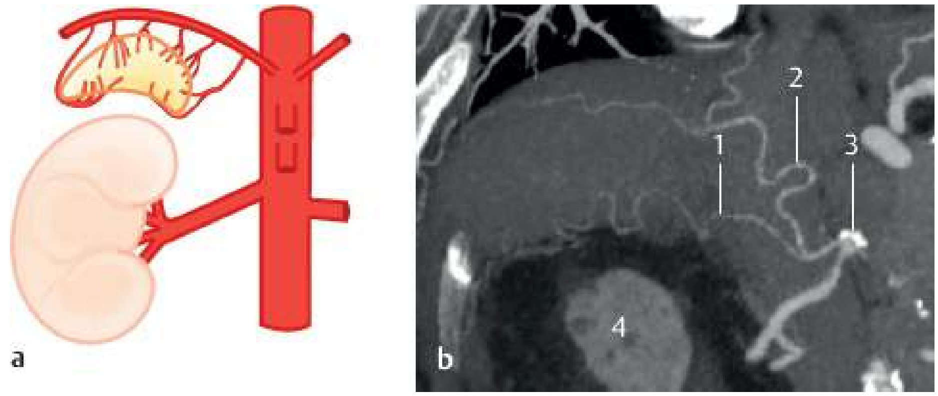

Fig. 10.5 From the inferior phrenic artery (2%). Schematic (**a**) and coronal oblique CT image (**b**). MIP showing blood supply of the right adrenal gland from the inferior phrenic artery, which in this case branches from the right renal artery. **1** Right suprarenal artery; **2** right phrenic artery; **3** right renal artery; **4** right kidney.

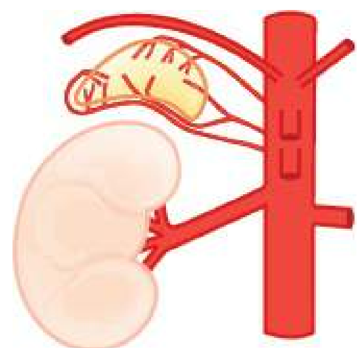

Fig. 10.6 From the aorta (1%). Schematic.

Fig. 10.7 From the renal artery (2%). Schematic (**a**), coronal oblique

MIP CT with blood supply (arrow) of the left adrenal gland (*) from the left renal artery (**b**), and DSA with blood supply (arrow) of the right adrenal gland (*) from the right renal artery (**c**). **1** Left renal artery; **2** right renal artery.

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11 Renal Artery

K.I. Ringe

The renal artery normally divides into two main trunks, which after branching in most cases into 5 to 7 arteries (range, 2–10) enter the parenchyma of the kidneys.[1–5] They have no anastomoses within the kidneys and are “end arteries,” which supply individual segments or parts of segments. Polar arteries are therefore not auxiliary, supplementary, or accessory arteries as they have been called, for they replace the normal segmental branch. Polar arteries and multiple renal arteries are important in kidney transplantation.[6]

Renal segments have been included in the official anatomical nomenclature. Their functional relevance is debatable as the segments are based only on the arterial supply, but the arterial pattern can impact surgical approaches especially when nephron-sparing surgery is performed.[7–13t]

Atypical origins of the renal arteries are found more often in cases of ectopic or horseshoe-shaped kidneys but are also common in kidneys in normal positions. Ectopic origins of renal arteries have been described in individual cases from the following arteries: median sacral, external and internal iliac, lumbar, superior and inferior mesenteric, branches of the celiac trunk, and even cranial to the celiac trunk from the aorta.[14–20]

The high frequency of polar arteries, multiple arteries, and the origin of renal arteries from the aorta at different heights or from other arteries can be explained by the embryological development of the kidney. Many segmental arteries supply the pronephros, followed by the more cephalad mesonephros and finally the metanephros. There is a continuous involution of arteries and growth of new renal arteries. The persistence of some of these segmental arteries results in multiple renal arteries, polar arteries, or an abnormal origin of a renal artery.[1,4,16,21–35]

Although the right kidney has a more caudal position than the left kidney, the right renal artery originates, in general, more cranial to the aorta than the left renal artery.[1,21,22,30,34,36] The right renal artery is longer than the left one because of the position of the aorta on the left of the vertebral column. The right renal artery usually runs posteriorly to the inferior vena cava and only anteriorly in about 4% of all cases when a single renal artery is present. In patients with two right renal arteries (in about 30%), one artery crosses the vena cava anteriorly.

There is considerable disagreement in the literature on the frequency of multiple renal arteries.[37] This can, in part, be explained by the technical differences, for example, anatomical or corrosion cast preparation, aortographies, or selective renal arteriograms. In some patients with hypertension or hydronephrosis, a higher frequency of multiple renal arteries was described,[38–42] although other studies showed no clear association between hypertension and accessory arteries.[43] Multiple arteries sometimes occurred more frequently on the left side. The percentages given in the figures are the mean for both kidneys.

11.1 “Normal” Pattern as Described in Textbooks (59%)

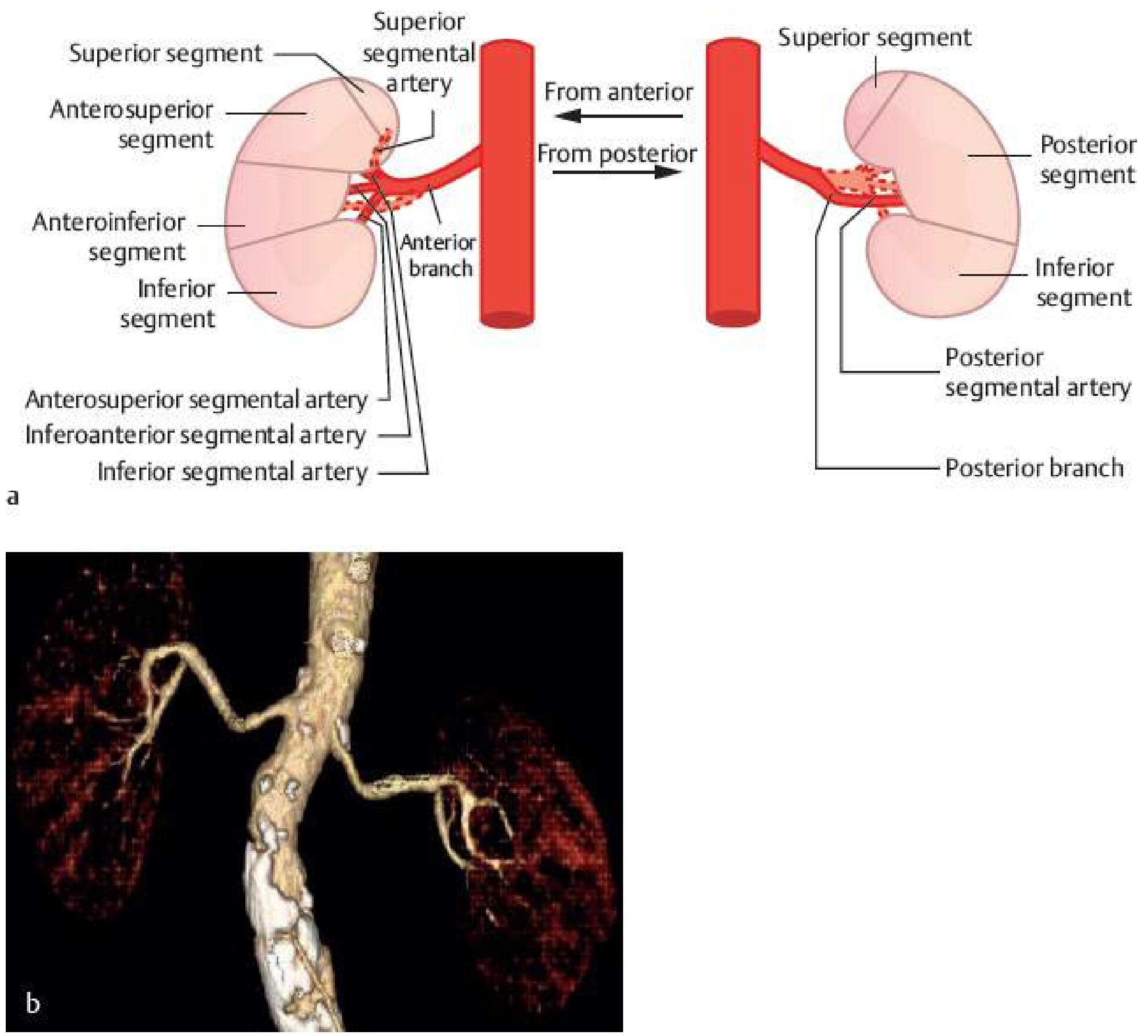

Fig. 11.1 "Normal" pattern as described in textbooks (59%). Schematic of the right kidney (**a**) and coronal VR CT with normal branching patterns of the right and left renal arteries (**b**). In addition, marked atherosclerosis of the abdominal aorta can be appreciated.

11.2 Polar Arteries from the Renal Artery (15%)

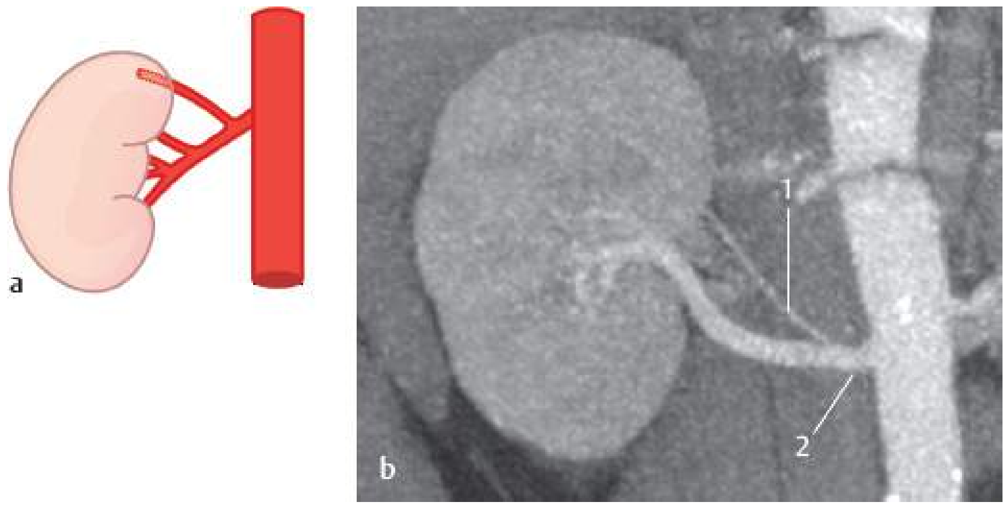

Fig. 11.2 Upper polar artery from the main stem of the renal artery (13%). Schematic (**a**) and coronal MIP CT (**b**). **1** Upper polar artery; **2** renal artery.

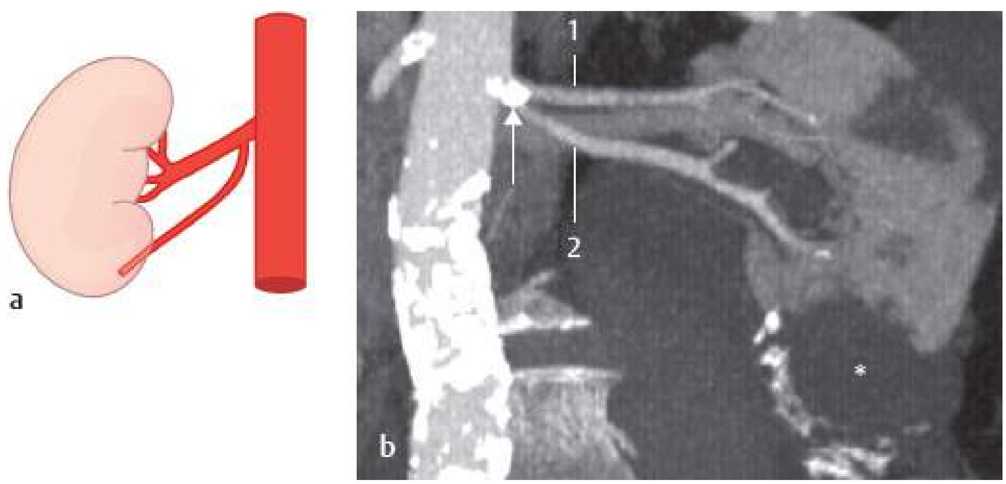

Fig. 11.3 Lower polar artery from the main stem of the renal artery (2%). Schematic (**a**) and coronal MIP CT (**b**). Distinct atherosclerosis of the abdominal aorta is present. Status post stent implantation in the proximal main stem of the left renal artery (arrow). In addition, a complicated cyst in the lower pole of the left kidney can be appreciated (*). **1** Renal artery; **2** lower polar artery.

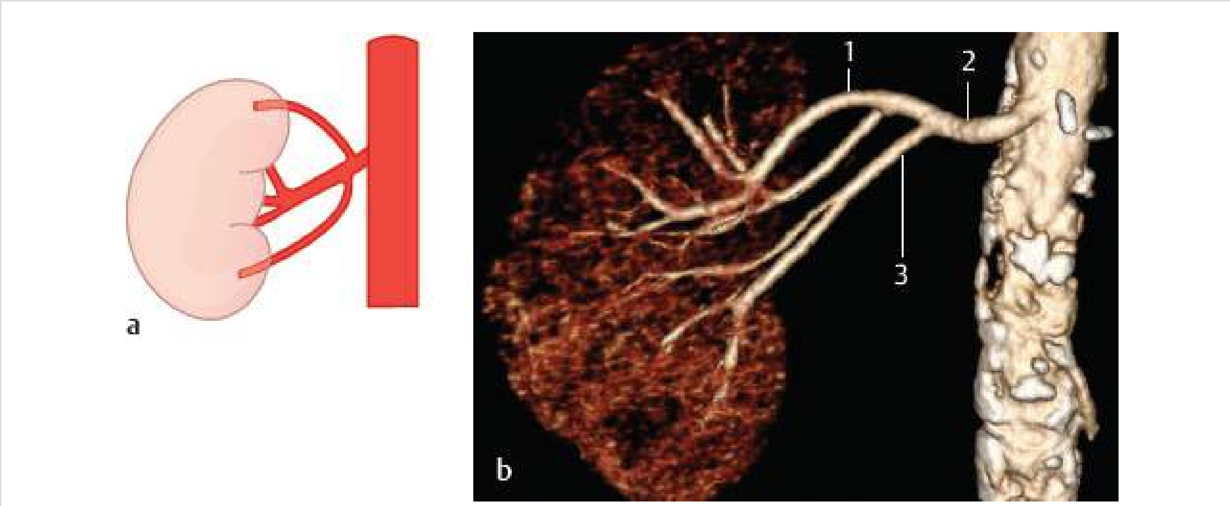

Fig. 11.4 Upper and lower polar arteries from the main stem of the renal artery (<1%). Schematic (**a**) and oblique coronal VR CT with upper and lower polar artery from the main stem of the renal artery (**b**). **1** Upper polar artery; **2** renal artery; **3** lower polar artery.

11.3 Two Renal Arteries (22%)

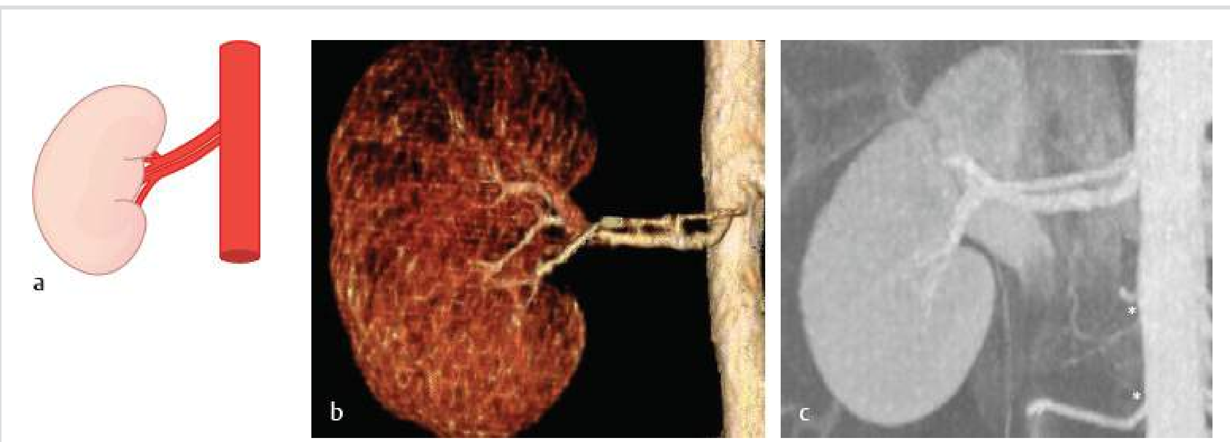

Fig. 11.5 Both renal arteries run to the hilus of the kidney (10%). Schematic (**a**) and CT (**b,c**). Oblique coronal VR (**b**) and coronal MIP (**c**) with two renal arteries on the right side. Lumbar arteries (*).

Fig. 11.6 Upper polar artery from the aorta (7%). Schematic (**a**) and CT images from two patients (**b,c**). ***Patient 1***: coronal MIP (**b**); the patient has a large parapelvinic cyst (*). ***Patient 2***: coronal VR (**c**); the patient has an infrarenal abdominal aneurysm (*).

1 Upper polar artery; **2** left renal artery.

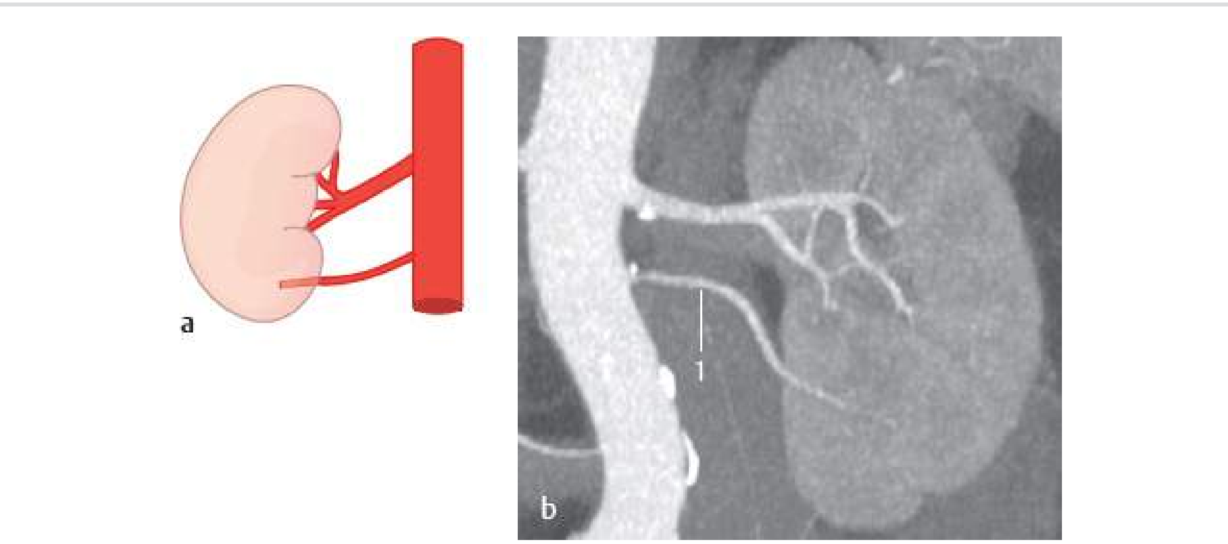

Fig. 11.7 Lower polar artery from the aorta (5%). Schematic (**a**) and coronal MIP CT (**b**). **1** Lower polar artery.

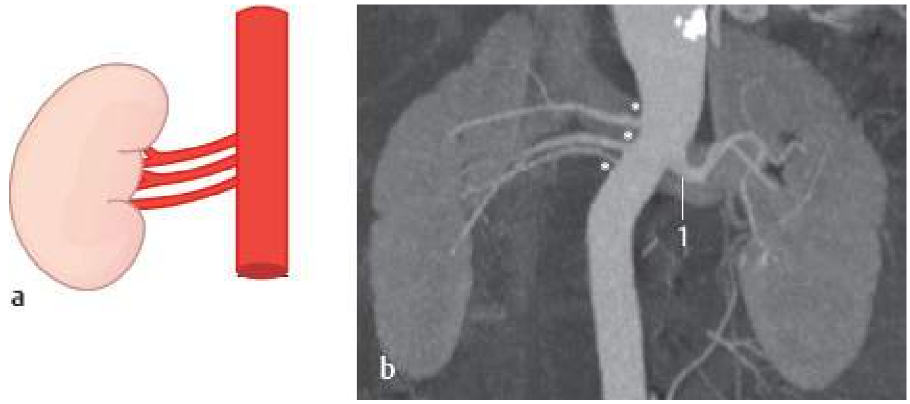

Fig. 11.8 All three renal arteries run to the hilus (1%). Schematic (**a**) and coronal MIP CT (**b**). The CT shows three separate renal arteries (*) running to the hilus on the right side. **1** Left renal artery.

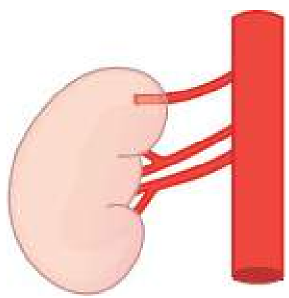

Fig. 11.9 Upper polar and two hilar arteries from the aorta (1%). Schematic.

11.4 Three or More Renal Arteries (4%)

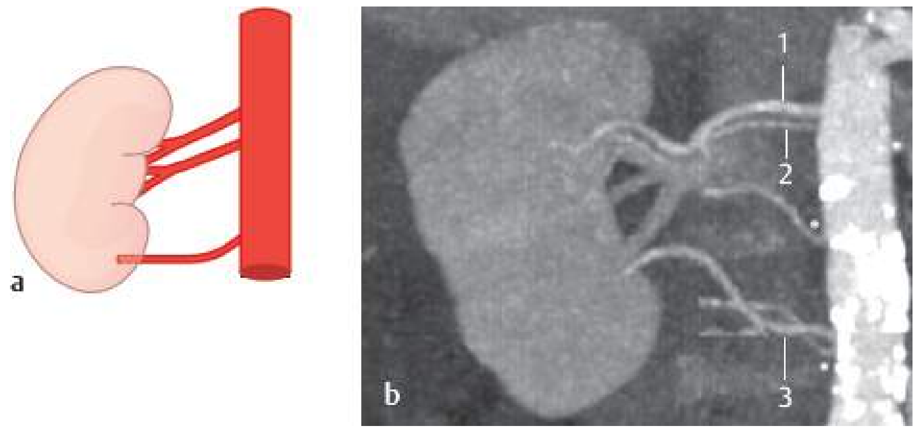

Fig. 11.10 Lower polar and two hilar arteries from the aorta (1%). Schematic (**a**) and coronal MIP (**b**). The CT shows the right kidney with lower polar (**3**) and two hilar (**1, 2**) arteries from the aorta. In addition, lumbar arteries (*) can be seen.

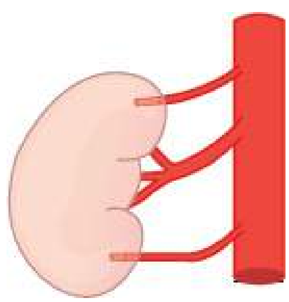

Fig. 11.11 Upper and lower polar artery from the aorta (<1%). Schematic.

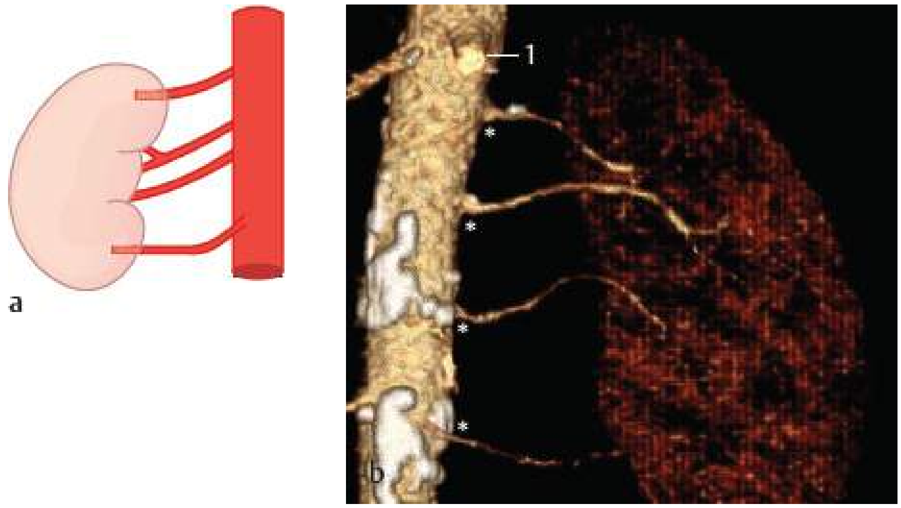

Fig. 11.12 Four renal arteries (because of the rare incidence, no further classification is given) (<1%). Schematic (**a**) and coronal VR CT of the left kidney with four renal arteries (*) (**b**). **1** Superior mesenteric artery.

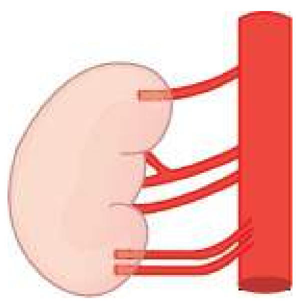

Fig. 11.13 Five renal arteries (numerous combinations) (<0.1%). Schematic.

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12 Testicular Artery

K.I. Ringe

In older studies and textbooks, the testicular and ovarian arteries were subsumed under the term internal spermatic artery.[1–3] Thus, in some studies on variations of these arteries the sex was not mentioned in which the abnormalities were observed.[1,4–6] In general, deviations in the origin and course of the testicular and ovarian arteries seem to be comparable. Only the testicular artery is shown in the figures in this chapter, since there are more studies on anomalies of the testicular arteries.[7–11] Only a small number of groups have done routine angiographies of the small testicular arteries.[12–14] In some rare cases, the testicular arteries arch over the renal arteries first before they turn toward the inguinal canal.[1,15] An anastomosis between the artery of the ductus deferens and the testicular artery has sometimes been found along the epididymis.[16]

12.1 Testicular Arteries Originating Only from the Aorta (83%)

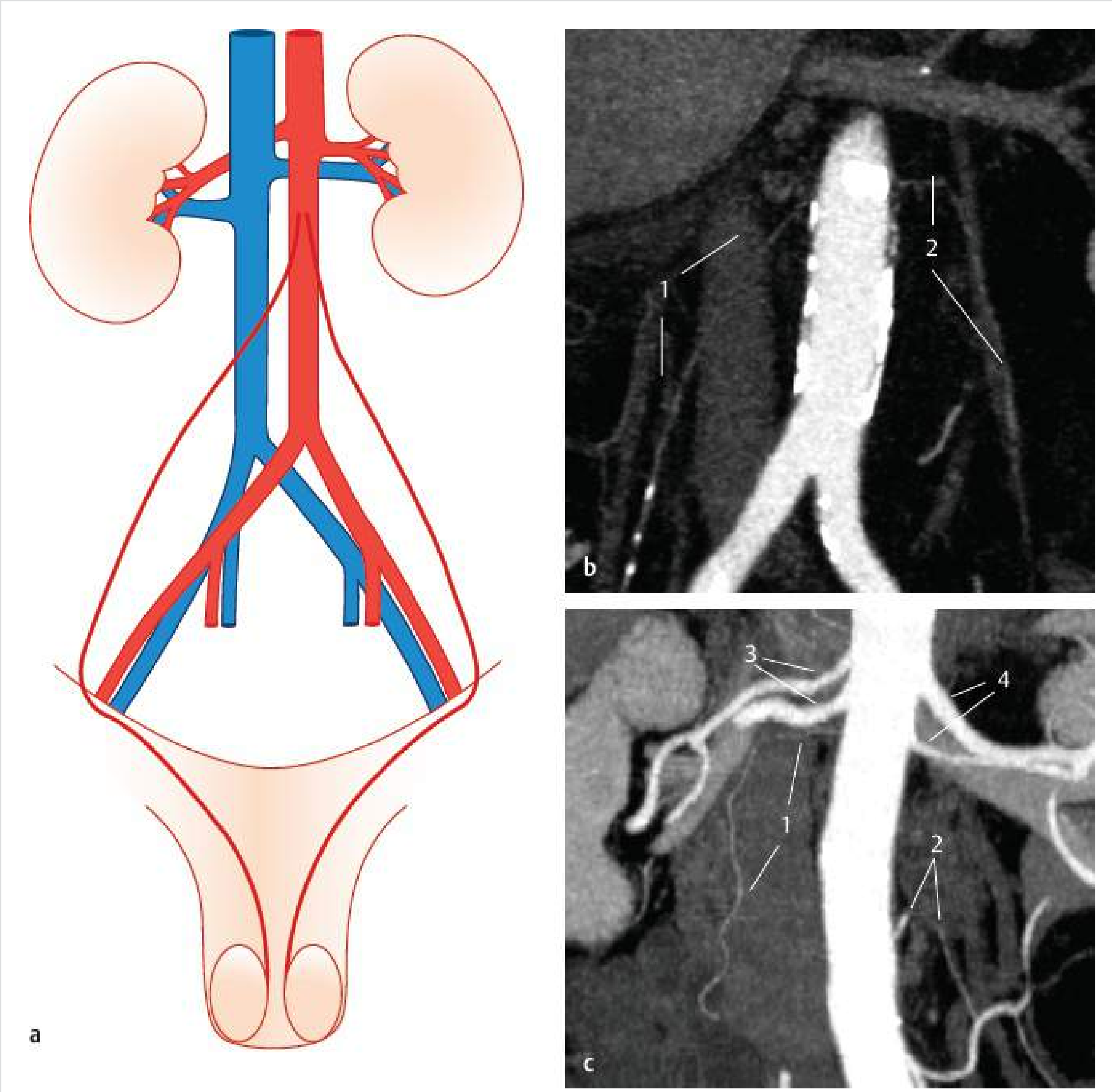

Fig. 12.1 Normal situation as found in textbooks (~68%). On each side, one testicular artery arises from the infrarenal aorta. Schematic (**a**) and coronal MIP CT images from two patients (**b,c**). In image **c** the left testicular artery branches distinctly lower; in addition, two renal arteries are present on both sides. **1** Right testicular artery; **2** left testicular artery; **3** right renal arteries; **4** left renal arteries.

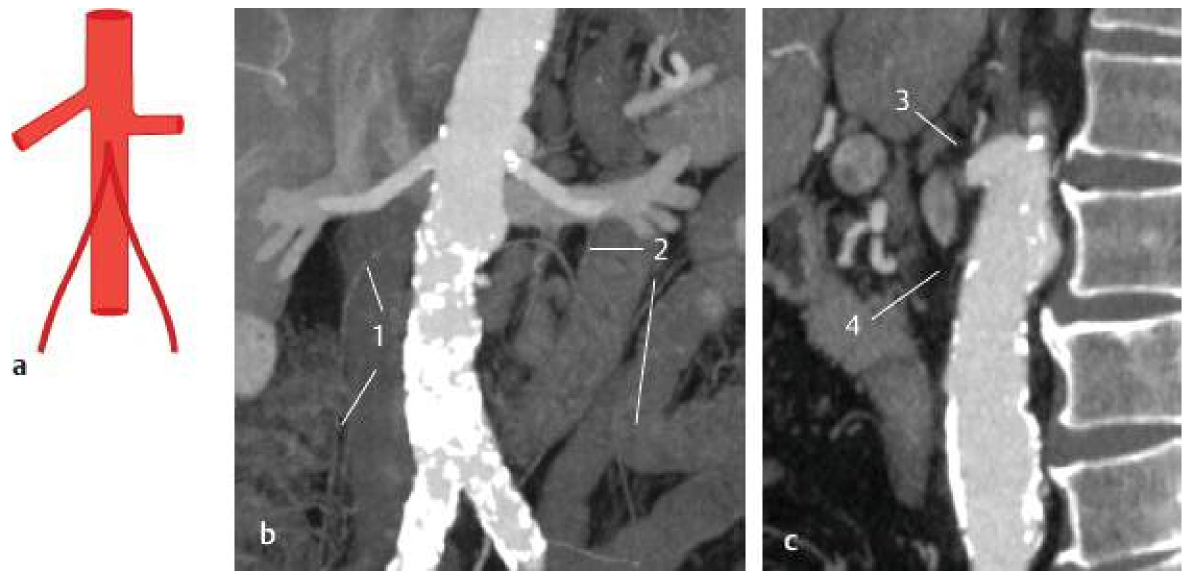

Fig. 12.2 The right and left testicular arteries form a common initial trunk (<0.1%). Schematic (**a**) and MIP CT (**b,c**). Coronal (**b**) and sagittal (**c**) view of the infra-renal aorta with the right and left testicular artery branching from a common trunk from the aorta. **1** Right testicular artery; **2** left testicular artery; **3** left renal artery; **4** common trunk.

Fig. 12.3 One testicular artery has two or more joining roots (<1%). Schematic.

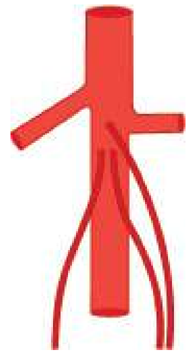

Fig. 12.4 Two testicular arteries on the left side (8%). Schematic.

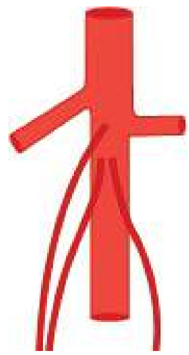

Fig. 12.5 Two testicular arteries on the right side (4%). Schematic.

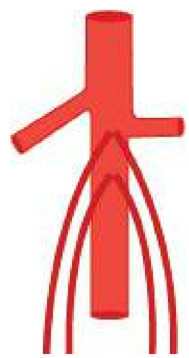

Fig. 12.6 Two testicular arteries on each side (2%). Schematic.

Fig. 12.7 Three testicular arteries are found on one side (more often on the left than on the right side) (<1%). Schematic.

12.2 Testicular Arteries Also Originating from the Renal Artery (17%)

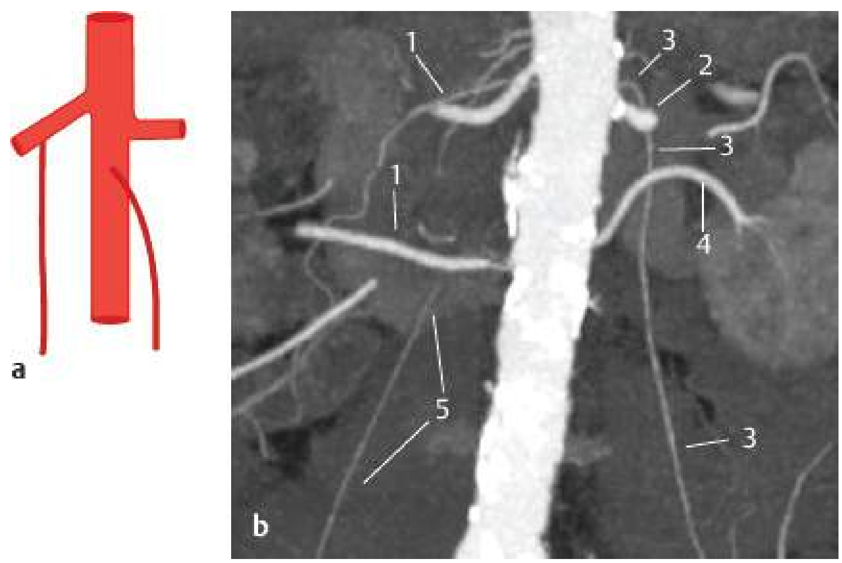

Fig. 12.8 Right testicular artery from the right renal artery (6%). Schematic (**a**) and coronal MIP CT (**b**). The CT image shows the right testicular artery arising from the right renal artery and the left testicular artery arising from the suprarenal aorta. Note that two renal arteries are present on both sides. **1** Right renal arteries; **2** left renal artery; **3** left testicular artery; **4** left renal artery; **5** right testicular artery.

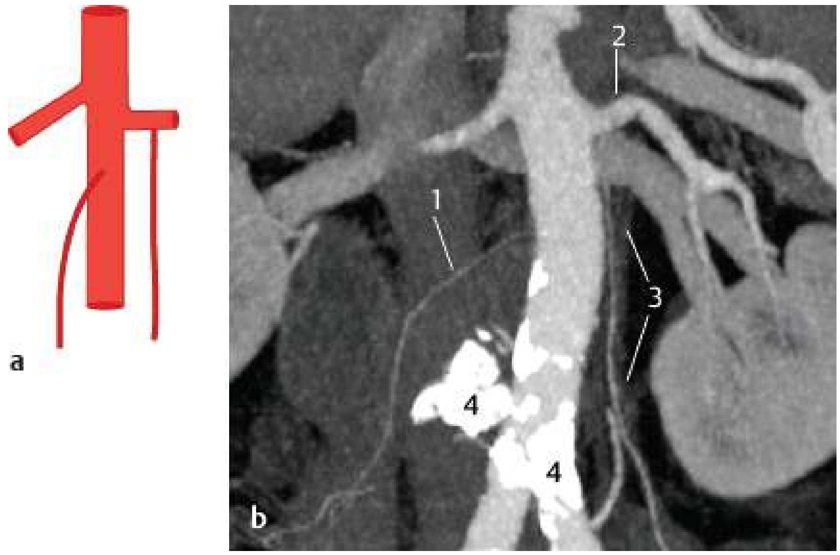

Fig. 12.9 Left testicular artery from the left renal artery (4%). Schematic (**a**) and coronal MIP CT (**b**). **1** Right testicular artery; **2** left renal artery; **3** left testicular artery; **4** atherosclerosis.

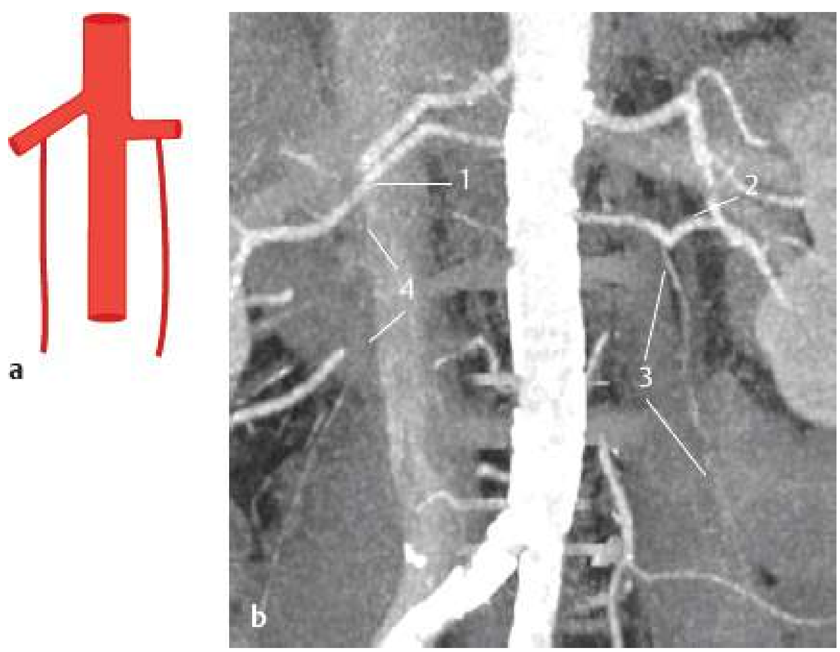

Fig. 12.10 Both testicular arteries from the renal arteries (4%). Schematic (**a**) and coronal MIP CT (**b**). **1** Right renal artery; **2** left renal artery; **3** left testicular artery; **4** right testicular artery.

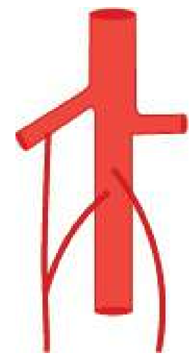

Fig. 12.11 One artery stems from both the aorta and a renal artery (<1%). Schematic.

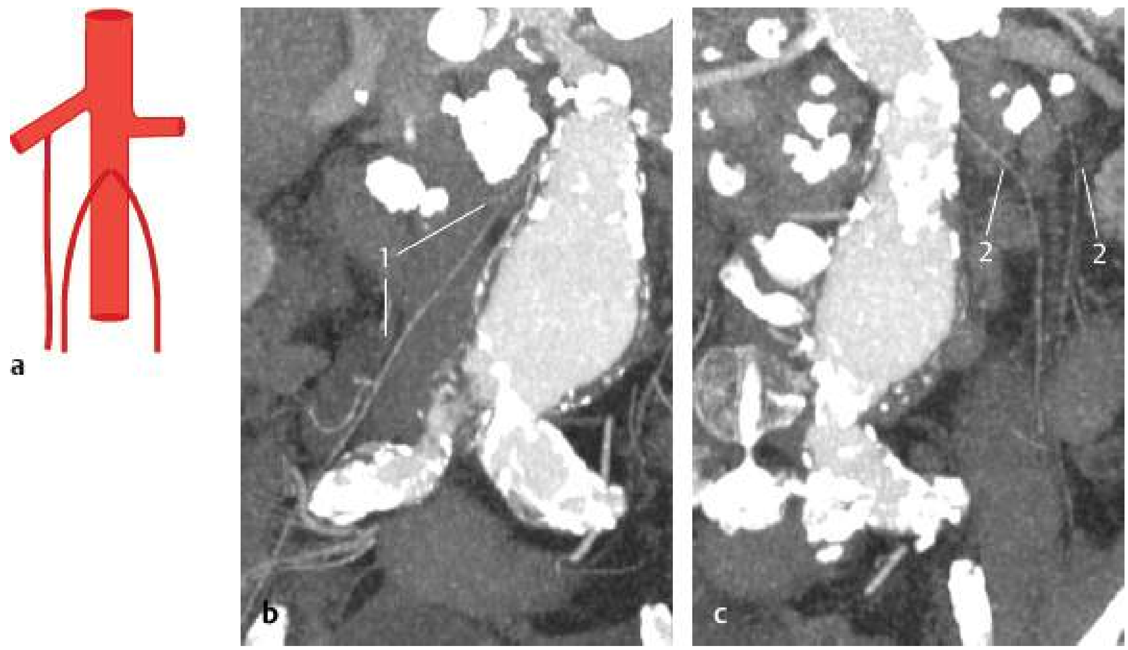

Fig. 12.12 Two testicular arteries on one side, one from the aorta and the other from the renal artery (<1%). Schematic (**a**) and oblique coronal MIP CT (two different angels) (**b,c**). In the CT, the right testicular artery arises from the aorta (**b**), and there are two left testicular arteries (**c**), one from the aorta and one from the renal artery. **1** Right testicular artery; **2** left testicular artery.

Fig. 12.13 Two right testicular arteries from the right renal artery (1%). Schematic.

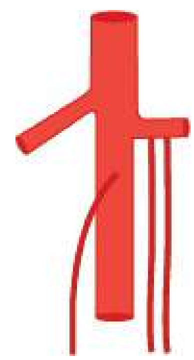

Fig. 12.14 Two left testicular arteries from the left renal artery (<1%). Schematic.

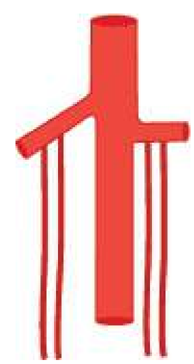

Fig. 12.15 Two testicular arteries on both sides from the renal arteries (1%). Schematic.

12.3 Testicular Arteries from Other Vessels (<1%)

Several cases of testicular arteries arising from the middle arteries, the common iliac, internal iliac, or inferior epigastric suprarenal artery have been described, but origins from lumbar arteries were found in individual cases only.

12.4 Course of the Testicular Arteries

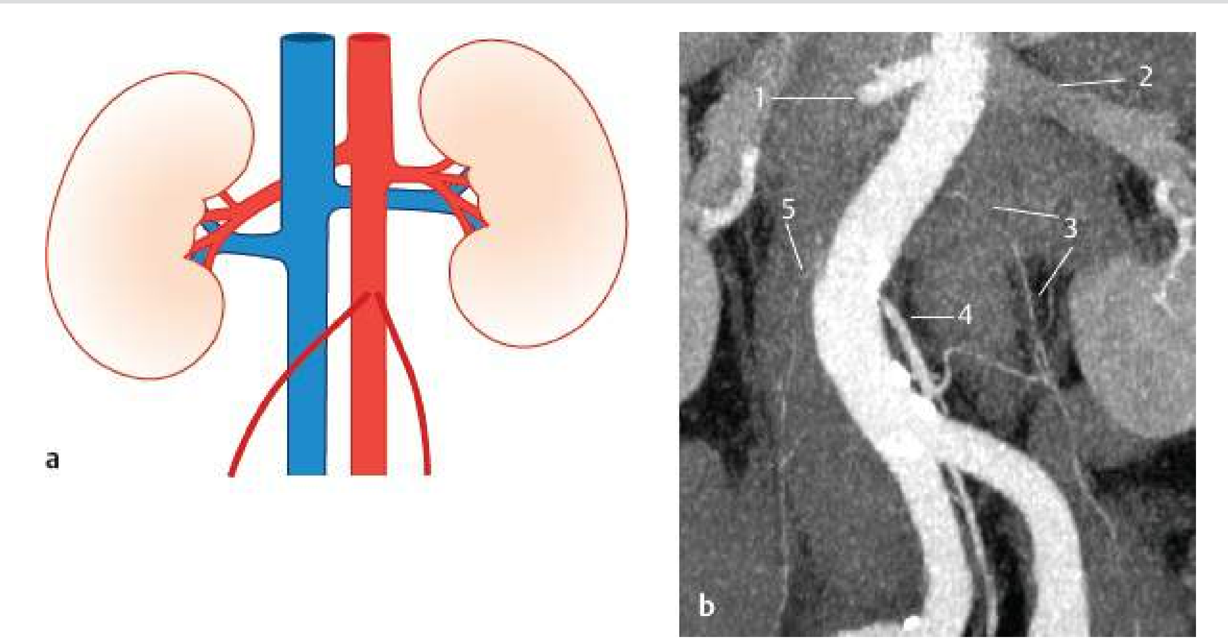

Fig. 12.16 The testicular arteries arise caudally to the renal veins (~80%). Schematic (**a**) and coronal MIP CT (**b**). **1** Right renal artery; **2** left renal vein; **3** left testicular artery; **4** Inferior mesenteric artery; **5** right testicular artery.

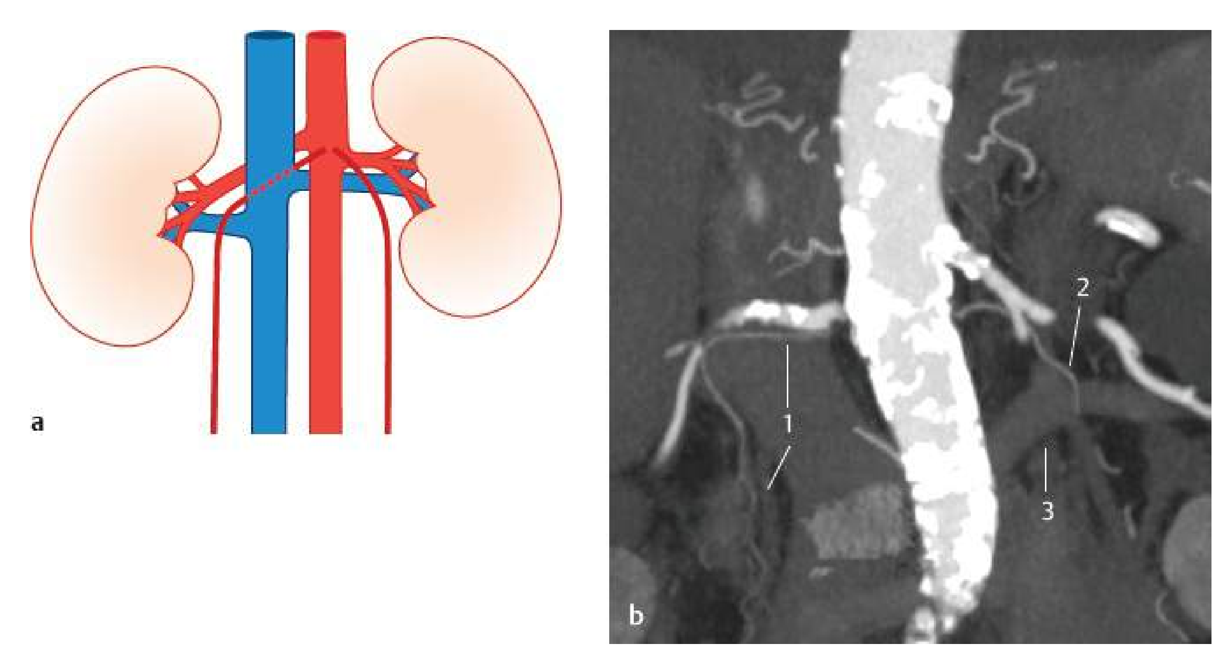

Fig. 12.17 The testicular arteries run ventrally to the renal veins (~20%). This is especially the case when a high origin is present or multiple arteries occur. The right testicular artery is located posterior to the inferior vena cava in such cases. These anomalies can impede the venous return.[1,9,15] Schematic (**a**) and coronal MIP CT (**b**). **1** Right testicular artery; **2** left testicular artery; **3** renal vein.

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13 Celiac Trunk

K.I. Ringe

Of the three main branches of the celiac trunk, the common hepatic artery has the highest frequency of anomalies.[1] For details of anomalies of the hepatic, left gastric, and splenic artery, see Chapters 14, 16, and 17. When a complete trunk is described (**Fig. 13.1**), this does not mean that the common hepatic artery has all “normal” branches, but only that a major part of the common hepatic artery, for example, the gastroduodenal artery, arises from the celiac trunk. An accessory hepatic artery from the superior mesenteric or left gastric artery was not included in this chapter. As in **Fig. 13.10** (hepatomesenteric trunk), only those cases have been included in which no major part of the common hepatic artery comes from the celiac trunk. A clear-cut differentiation between the types shown in **Fig. 13.1** and **Fig. 13.2** is not always possible. The most frequent accessory branch is the inferior phrenic artery (in ~50%; see Chapter 9). In this chapter, only variations of the typical branches of the celiac trunk are included.[2–19]

The origins from the aorta of the celiac trunk and the superior mesenteric artery are close to each other and they quite often form common trunks.[18,20] For the sake of clarity, the origins are drawn further apart than is the case in situ.

13.1 Complete Celiac Trunk (Gastrohepatolienal Trunk) (84%)

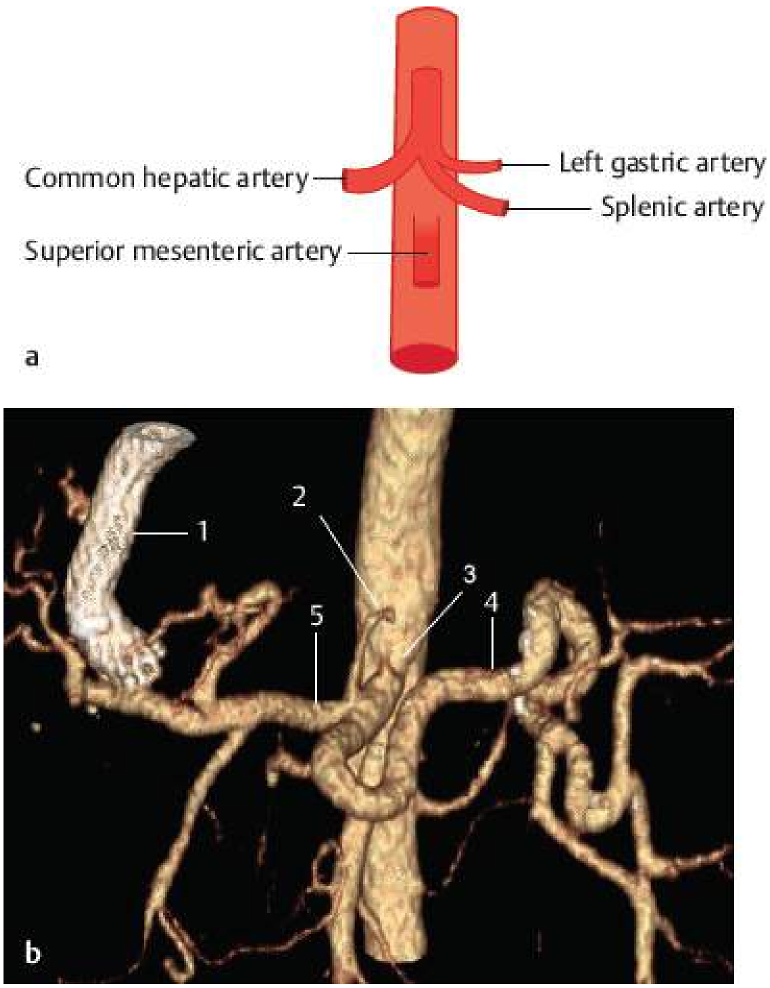

Fig. 13.1 “Normal” type as seen in textbooks: the celiac trunk is formed by the left gastric common hepatic and splenic artery (tripus Halleri) (~25%). Schematic (**a**) and VR CT image (**b**) in a patient with portal hypertension and status post transjugular intrahepatic portosystemic shunt implantation. The CTA demonstrates a normal branching pattern of the celiac trunk. **1** Transjugular intrahepatic portosystemic shunt; **2** left gastric artery; **3** celiac trunk; **4** splenic artery; **5** common hepatic artery.

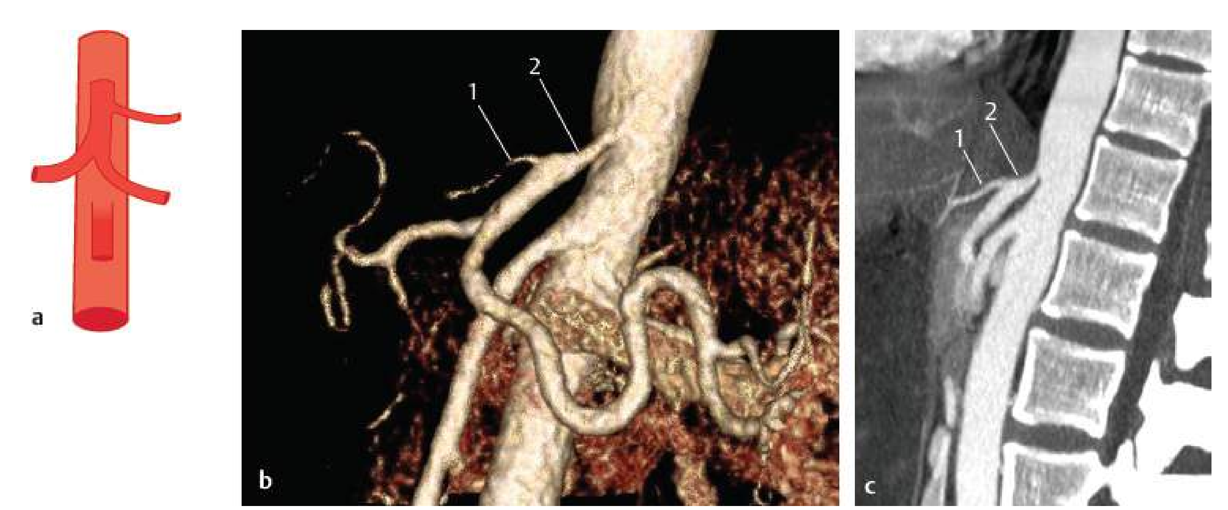

Fig. 13.2 The celiac trunk leaves the left gastric artery as a side branch and divides more distally into the common hepatic and the splenic artery (~49%). Schematic (**a**), coronal VR CT (**b**), and sagittal MIP CT (**c**). **1** Left gastric artery; **2** celiac trunk.

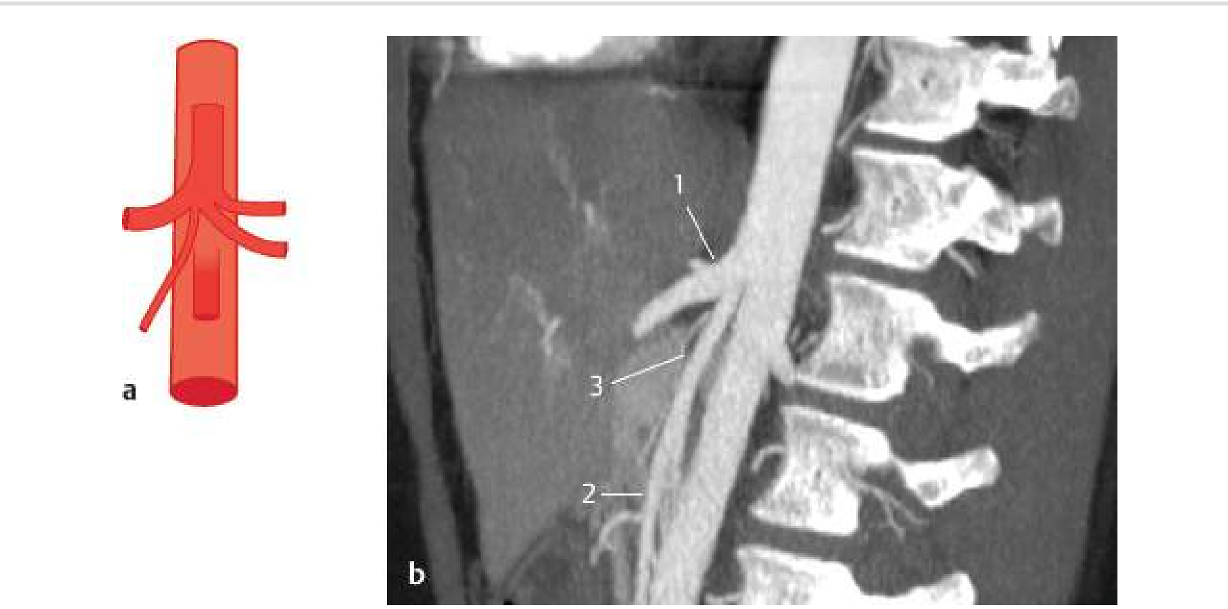

Fig. 13.3 The celiac trunk has four main branches (tetrapus), the fourth being an additional posterior pancreatic artery (10%). Schematic (**a**) and sagittal MIP CT (**b**). **1** Celiac trunk; **2** superior mesenteric artery; **3** posterior pancreatic artery.

13.2 Incomplete Celiac Trunk (9%)

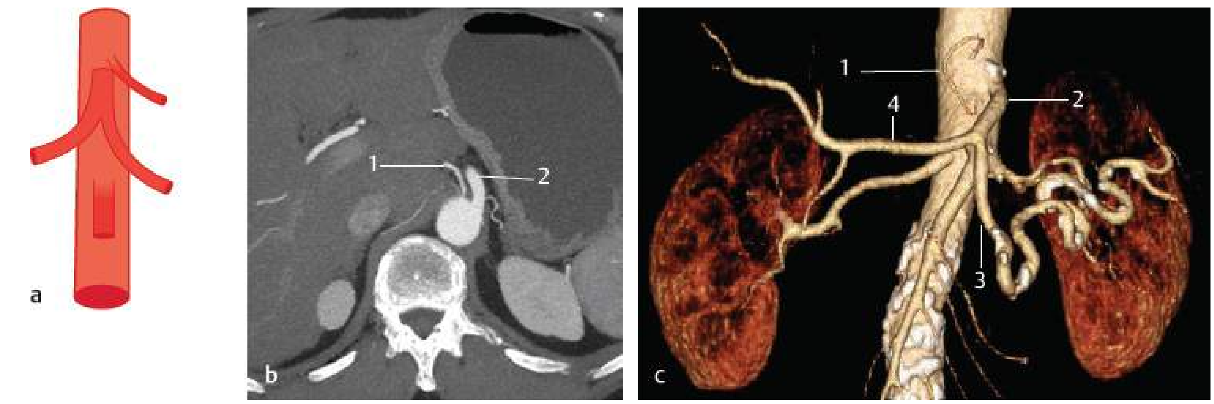

Fig. 13.4 Hepatosplenic trunk; the left gastric artery is a separate branch of the aorta (5%). Schematic (**a**), axial MIP CT at the level of the celiac trunk (**b**), and coronal VR CT (**c**). **1** Left gastric artery; **2** hepatosplenic trunk; **3** splenic artery; **4** common hepatic artery.

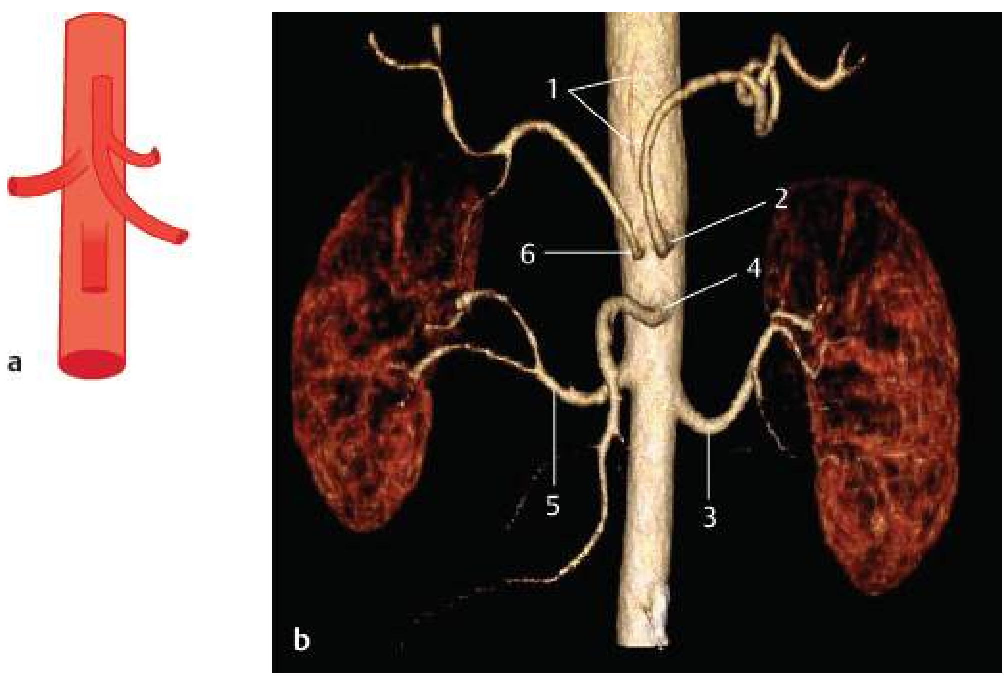

Fig. 13.5 Gastrosplenic trunk; the common hepatic artery is absent or an independent branch of the aorta (3%). Schematic (**a**) and 3D VR CT image (**b**). The CT image shows the celiac trunk with

the common hepatic artery as an independent branch of the aorta. **1** Left gastric artery; **2** splenic artery; **3** left renal artery; **4** superior mesenteric artery; **5** right renal artery; **6** common hepatic artery.

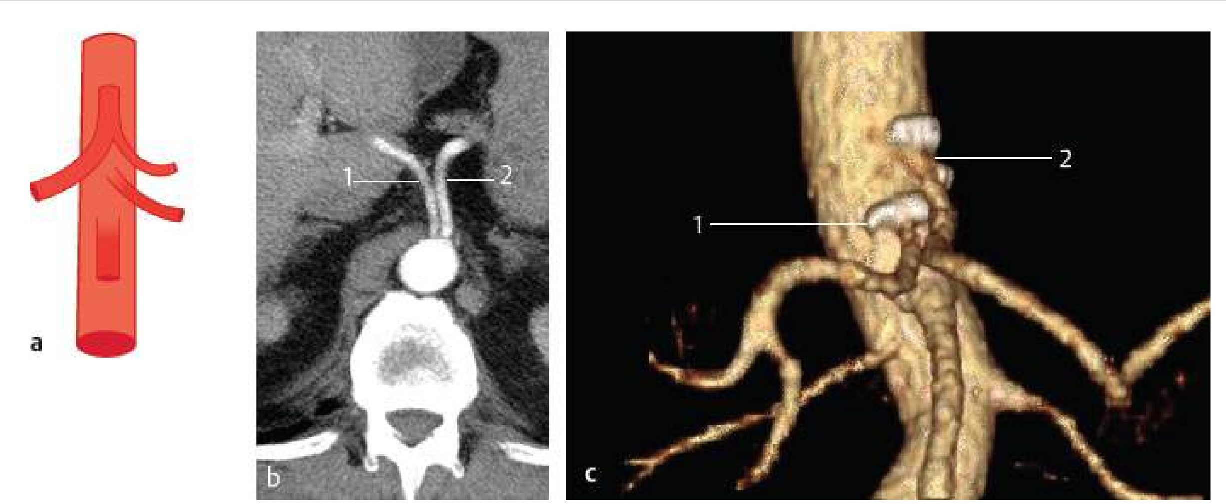

Fig. 13.6 Gastrohepatic trunk; the splenic artery is an independent branch of the aorta (1%). Schematic (**a**). axial MIP CT at the level of the celiac trunk (**b**), and coronal VR CT (**c**). **1** Gastrohepatic trunk; **2** splenic artery.

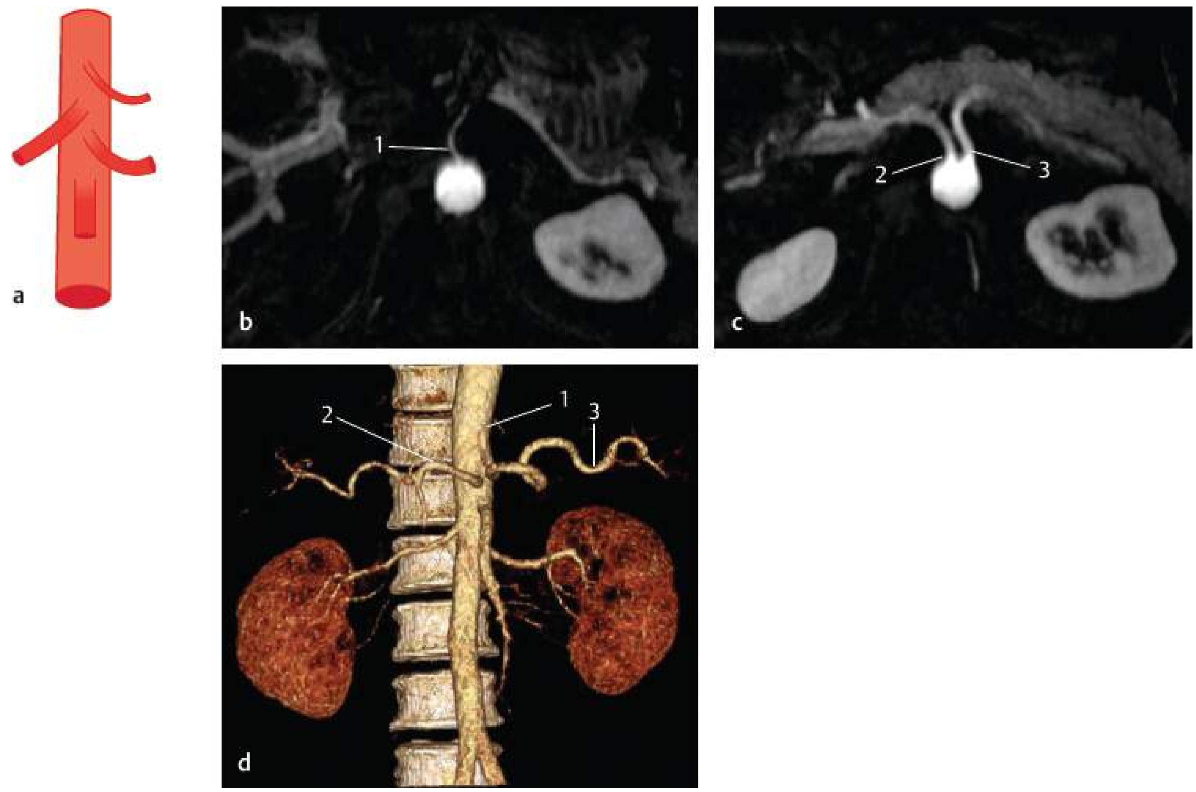

Fig. 13.7 No trunk formation (<1%). Schematic (**a**) and scans of two patients (**b–d**). ***Patient 1***: axial MIP of an MRI demonstrating separate branching of the left gastric artery from the abdominal aorta superior to the common hepatic artery and splenic artery; image **b** is superior to image **c.** ***Patient 2***: 3D VR CT image (**d**). **1** Left gastric artery; **2** common hepatic artery; **3** splenic artery.

13.3 Common Origin of Main Branches of the Celiac Trunk with the Superior Mesenteric Artery (7%)

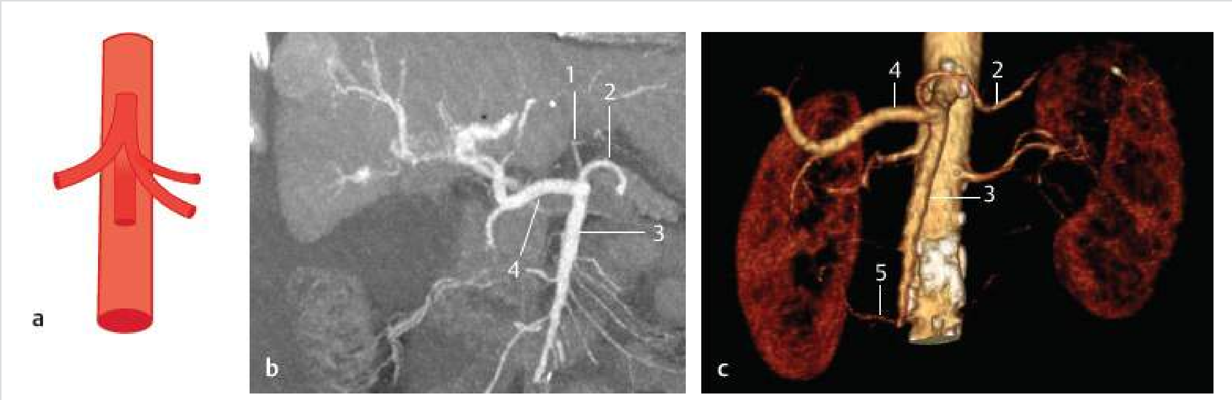

Fig. 13.8 Gastrohepato-splenomesenteric trunk (2%). Schematic (**a**) as well as coronal MIP (**b**) and coronal VR CT (**c**) in a patient with liver cirrhosis and an arterioportal shunt (*) in the liver hilum. In addition, a right lower polar renal artery can be appreciated. **1** Left gastric artery; **2** splenic artery; **3** superior mesenteric artery; **4** common hepatic artery; **5** lower pole artery.

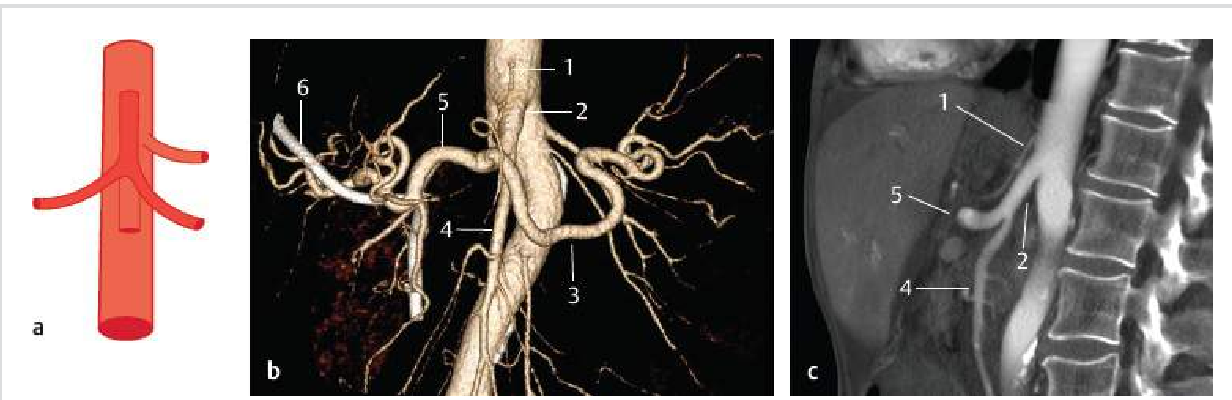

Fig. 13.9 Hepatosplenomesenteric trunk (1%). Schematic (**a**) as well as coronal oblique 3D VR CT image (b) and sagittal AvIP reformation (c). The left gastric artery is a separate branch from the abdominal aorta. In addition, a stent can be appreciated in the common bile duct. **1** Left gastric artery; **2** hepatosplenomesenteric trunk; **3** splenic artery; **4** superior mesenteric artery; **5** common hepatic artery; **6** stent.

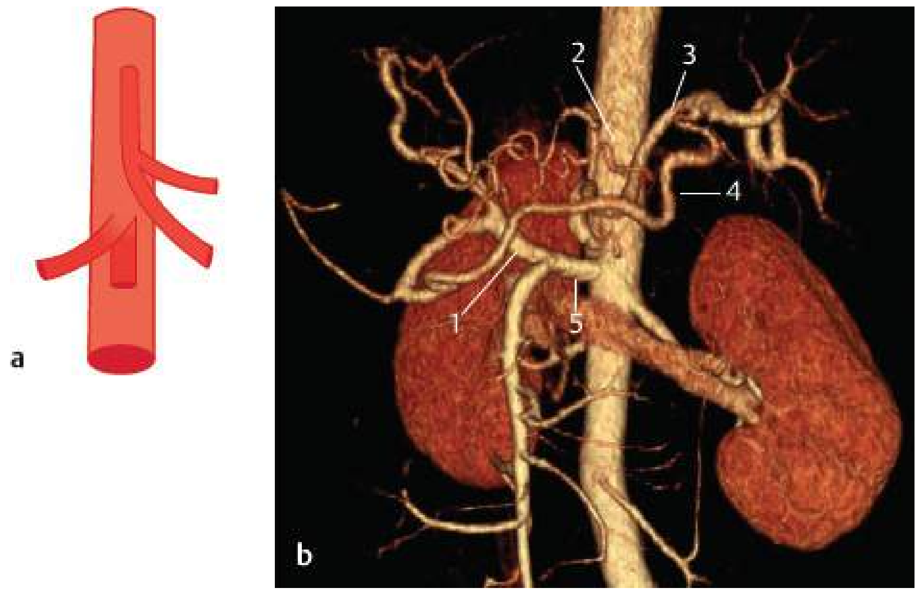

Fig. 13.10 Hepatomesenteric trunk (3%). Schematic (**a**) and coronal oblique 3D VR CT image (b) with the common hepatic artery arising from the superior mesenteric artery. In addition, high grade stenosis of the gastrosplenic trunk is present with strong gastroduodenal artery. **1** Common hepatic artery; **2** left gastric artery; **3** splenic artery; **4** gastroduodenal artery; **5** superior mesenteric artery.

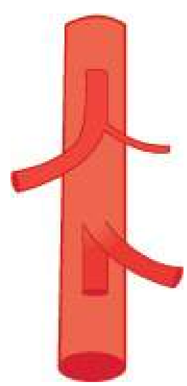

Fig. 13.11 Splenomesenteric trunk (1%). Schematic.

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14 Hepatic Arteries

K.I. Ringe

Like the lung, the liver can be subdivided into lobes and segments which are supplied by end arteries. These arteries, however, frequently have accessory branches. The branching pattern of the common hepatic artery into a left and right hepatic artery corresponds to the left and right lobe.[1–4]

The border between the functionally defined lobes is not the anatomical border but the line from the gallbladder to the sulcus of the inferior vena cava. Thus, the caudate and quadrate lobe are part of the left lobe and supplied with arterial blood in 90% of all cases by the left hepatic artery. The left lobe can be divided further into a medial and lateral segment, and the right lobe into an anterior and posterior segment.[5–33]

14.1 Arterial Blood Supply of the Liver from the Celiac Trunk Only (76%)

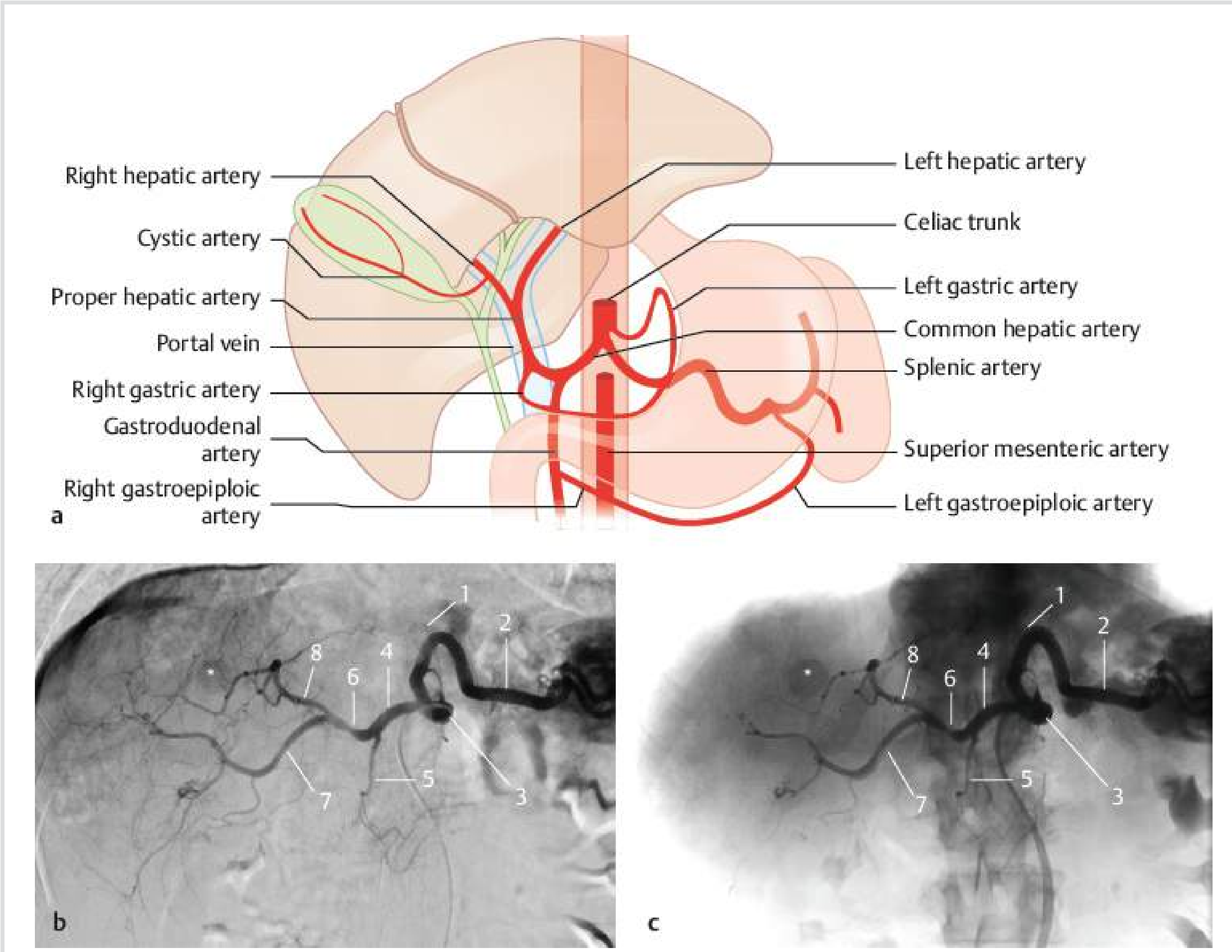

Fig. 14.1 “Normal” type shown in textbooks (50%). The common hepatic artery is a branch of the celiac trunk or originates directly from the aorta. Schematic (**a**) and subtracted (**b**) and nonsubtracted (**c**) DSA with a catheter placed in the celiac trunk. The patient underwent transarterial chemoembolization for hepatocellular carcinoma (*). **1** Left gastric artery; **2** splenic artery; **3** celiac trunk; **4** common hepatic artery; **5** gastroduodenal artery; **6** proper hepatic artery; **7** right hepatic artery; **8** left hepatic artery.

Fig. 14.2 Accessory hepatic artery from the celiac trunk or directly from the aorta, or a separate origin of the right and left hepatic arteries (2%). Schematic (**a**) as well as DSA (**b**) and coronal MIP CT (**c**) in a patient with an accessory hepatic artery from the celiac trunk. **1** Common hepatic artery; **2** left gastric artery; **3** splenic artery; **4** celiac trunk; **5** accessory hepatic artery; 6 superior mesenteric artery.

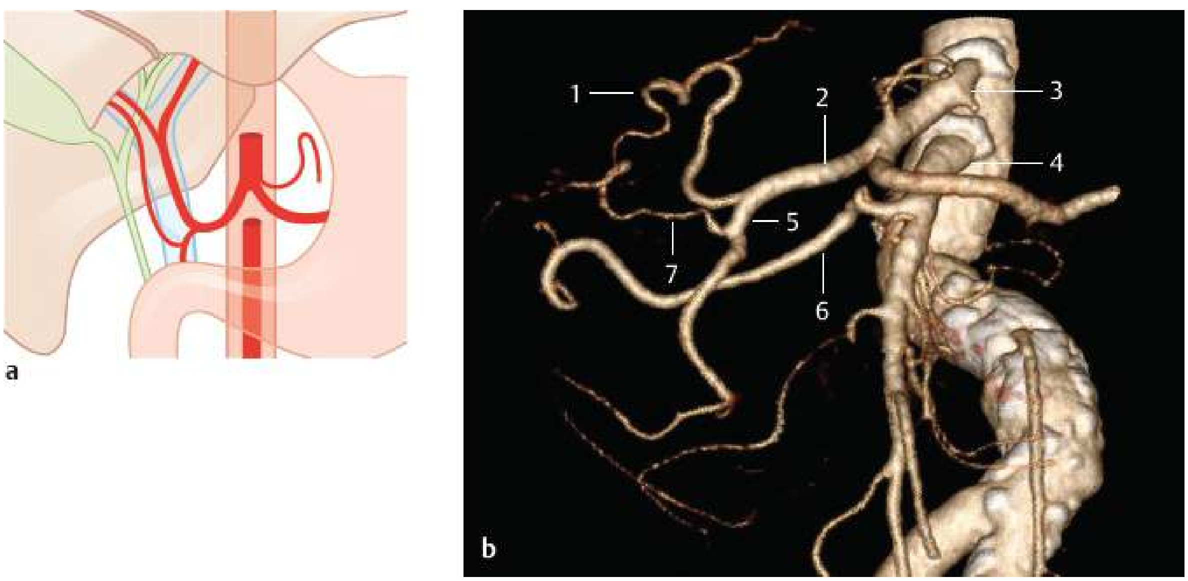

Fig. 14.3 Accessory hepatic artery from the gastroduodenal artery (2%). Schematic (**a**) and oblique coronal VR CT (**b**). The VR image shows the right hepatic artery arising from the superior mesenteric artery and an accessory hepatic artery arising from the gastroduodenal artery. In addition, kinking and profound sclerosis of the abdominal aorta are present. **1** Left hepatic artery; **2** common hepatic artery; **3**

celiac trunk; **4** superior mesenteric artery; **5** gastroduodenal artery; **6** right hepatic artery; **7** accessory right hepatic artery.

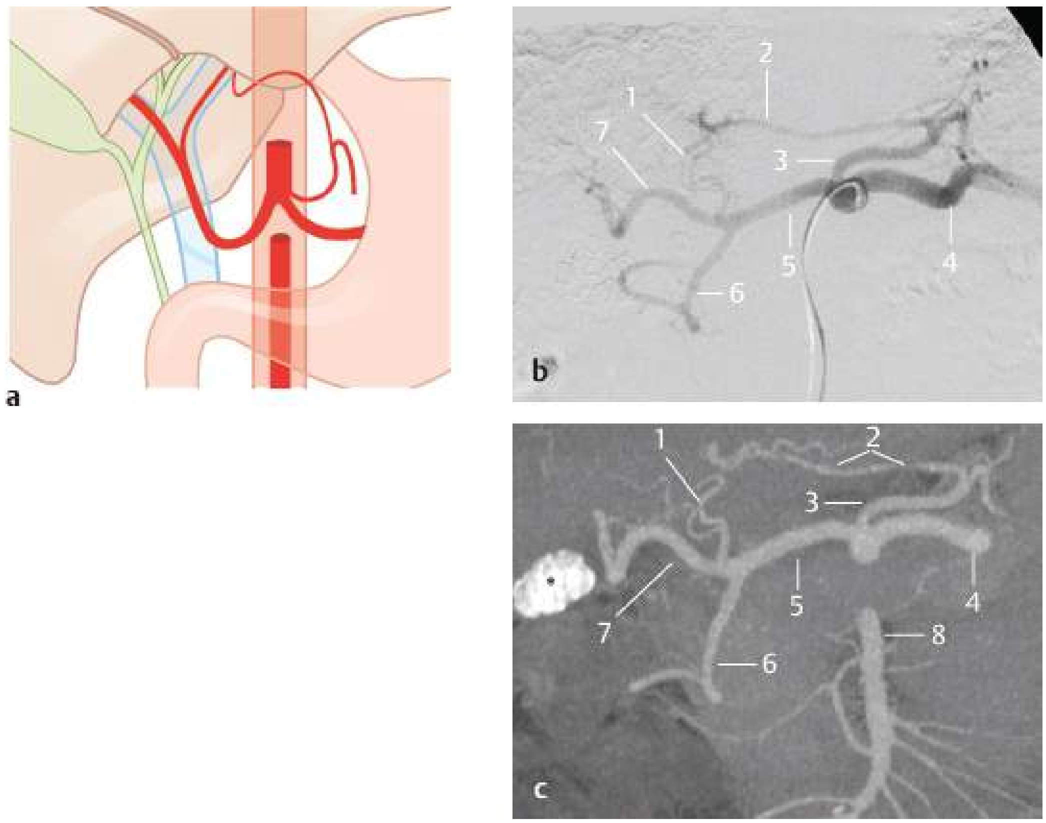

Fig. 14.4 Accessory left hepatic artery from the left gastric artery (12%). Schematic (**a**), as well as DSA (**b**) and coronal MIP CT (**c**) in a patient with cholecystolithiasis (*). **1** Left hepatic artery; **2** accessory left hepatic artery; **3** left gastric artery; **4** splenic artery; **5** common hepatic artery; **6** gastroduodenal artery; **7** right hepatic artery; **8** superior mesenteric artery.

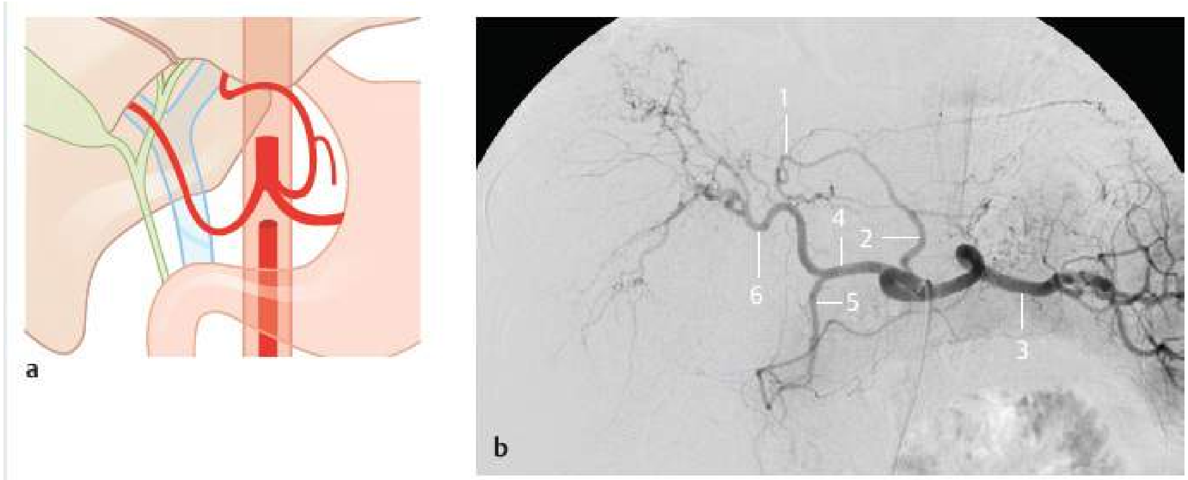

Fig. 14.5 Replaced left hepatic artery from the left gastric artery (3%). Schematic (**a**) and DSA (**b**). **1** Left hepatic artery; **2** left gastric artery; **3** splenic artery; **4** common hepatic artery; **5** gastroduodenal artery; **6** right hepatic artery.

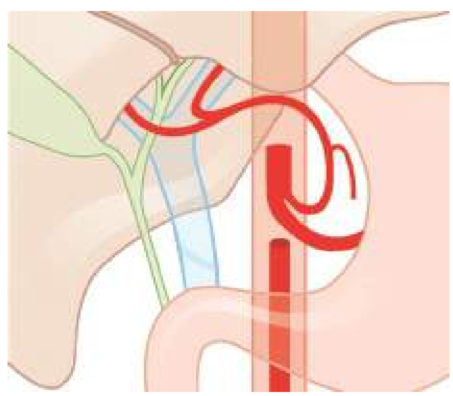

Fig. 14.6 Common hepatic artery from the left gastric artery (<1%). Schematic.

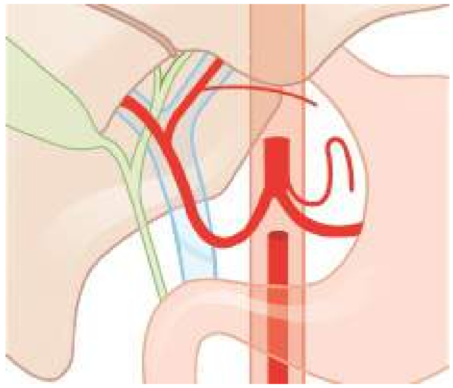

Fig. 14.7 Accessory left gastric artery from the left hepatic artery (7%). Schematic.

14.2 The Superior Mesenteric Artery Also Supplies the Liver (24%)

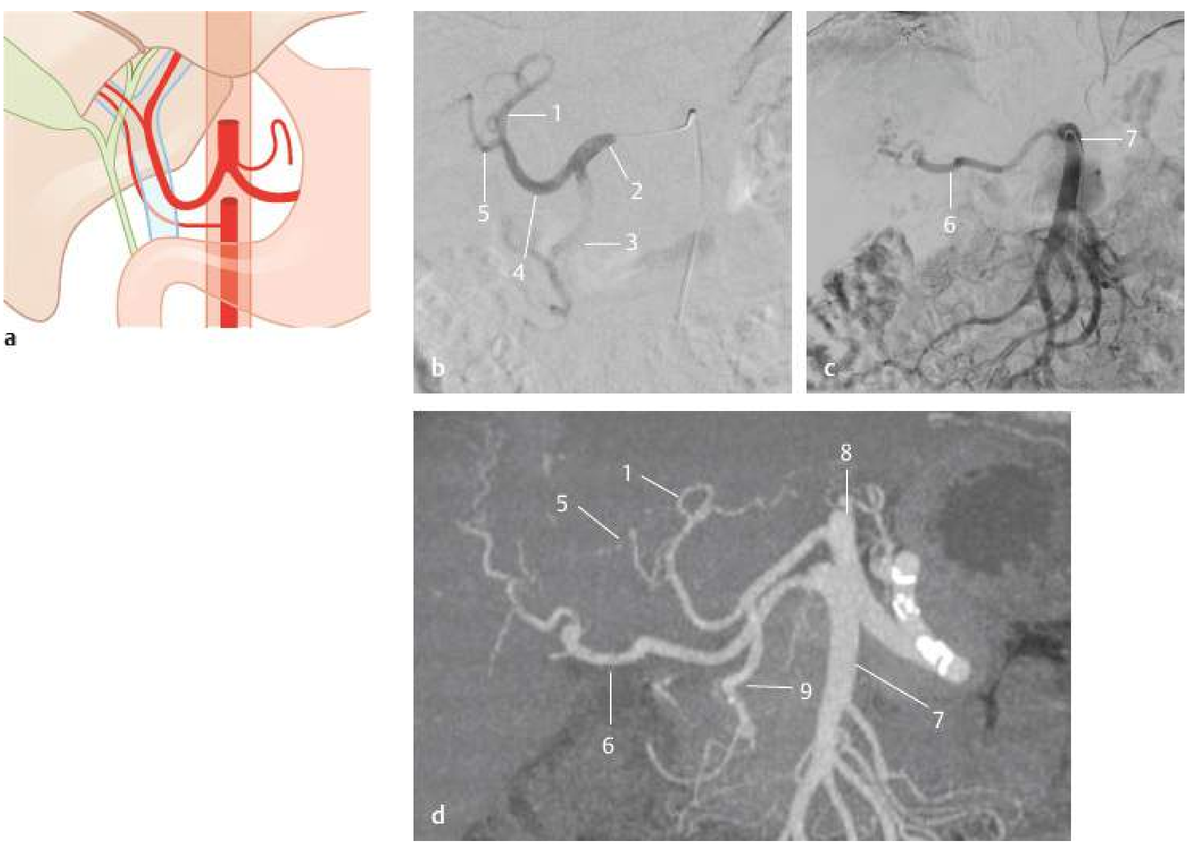

Fig. 14.8 Accessory right hepatic artery from the superior mesenteric artery (5%). Schematic (**a**), DSA with a diagnostic catheter placed in the common hepatic artery (**b**) and superior mesenteric artery (**c**), and coronal MIP CT (**d**). **1** Left hepatic artery; **2** common hepatic artery; **3** gastroduodenal artery; **4** proper hepatic artery; **5** right hepatic artery; **6** accessory right hepatic artery; **7** superior mesenteric artery; **8** celiac trunk; **9** gastroduodenal artery.

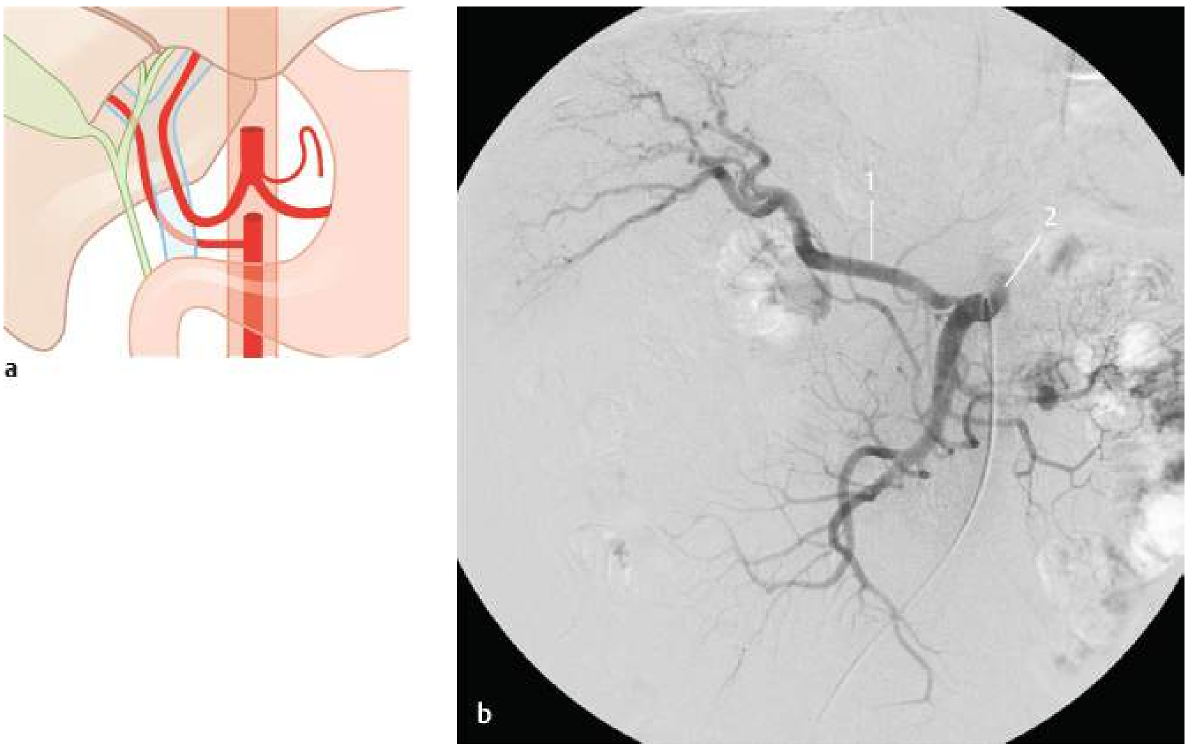

Fig. 14.9 Replaced right hepatic artery from the superior mesenteric artery (10%). Schematic (**a**) and DSA (**b**). **1** Right hepatic artery; **2** superior mesenteric artery.

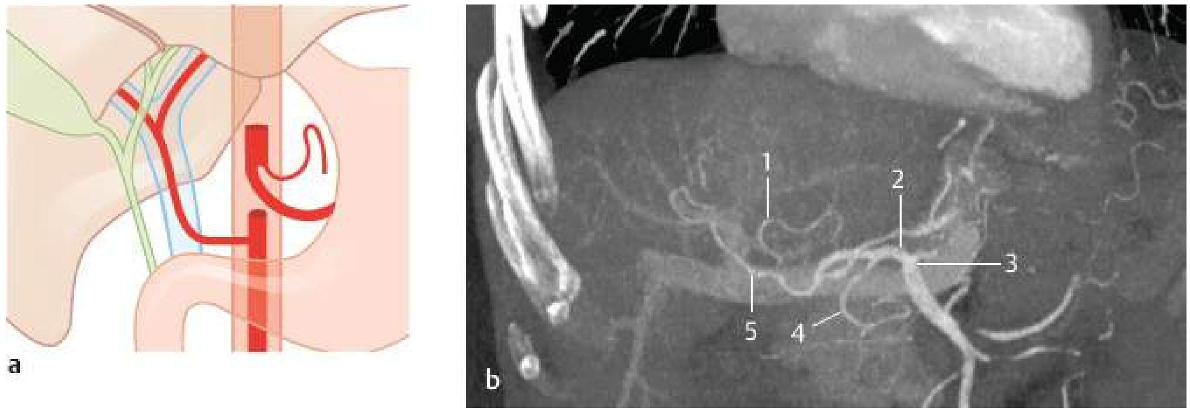

Fig. 14.10 Common hepatic artery from the superior mesenteric artery (hepatomesenteric trunk) (3%). Schematic (**a**) and coronal MIP CT (**b**). **1** Left hepatic artery; **2** common hepatic artery; **3** superior mesenteric artery; **4** gastroduodenal artery; **5** right hepatic artery.

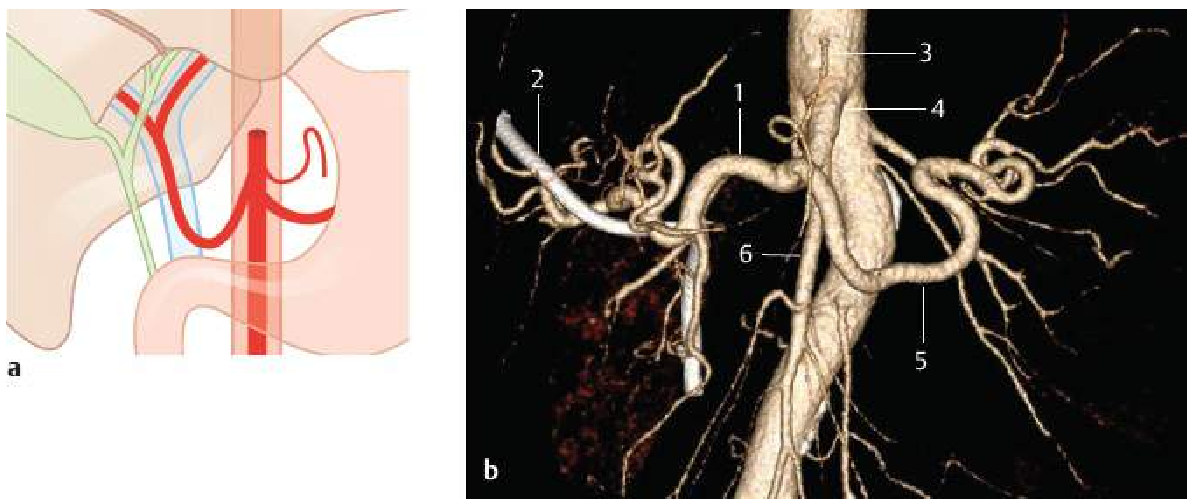

Fig. 14.11 Common hepatic artery from a four-branch trunk (gastrohepatosplenomesenteric trunk) or a hepatosplenomesenteric trunk (3%). Schematic (**a**) and coronal oblique 3D VR CT image with a hepatosplenomesenteric trunk (**b**). In the CT image, the left gastric artery is a separate branch from the abdominal aorta. In addition, a stent can be appreciated in the common bile duct. **1** Common hepatic artery; **2** stent; **3** left gastric artery; **4** hepatosplenomesenteric trunk; **5** splenic artery; **6** superior mesenteric artery.

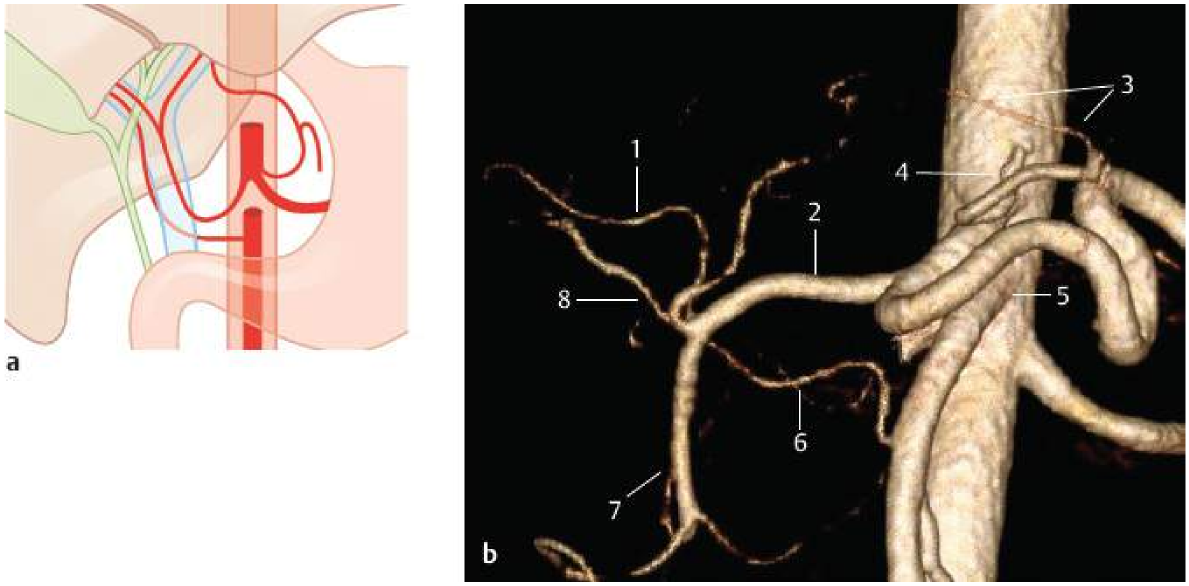

Fig. 14.12 Accessory right hepatic artery from the superior mesenteric and accessory left hepatic artery from the left gastric artery (1%). Schematic (**a**) and coronal oblique **3** D VR CT (**b**). **1** Left hepatic artery; **2** common hepatic artery; **3** accessory left hepatic artery; **4** left gastric artery; **5** superior mesenteric artery; **6** accessory right hepatic artery; **7** gastroduodenal artery; **8** right hepatic artery.

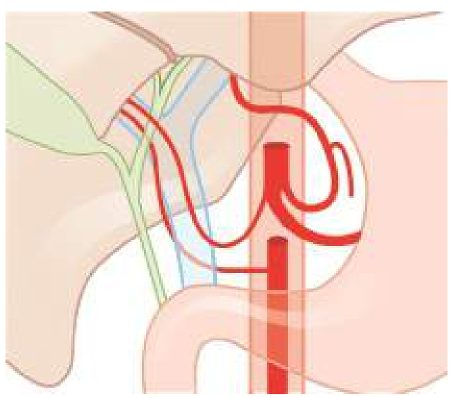

Fig. 14.13 Accessory right hepatic artery from the superior mesenteric and replaced left hepatic artery from the left gastric artery (<1%). Schematic.

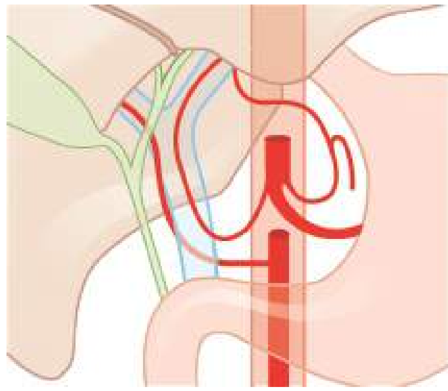

Fig. 14.14 Replaced right hepatic artery from the superior mesenteric and accessory left hepatic artery from the left gastric artery (1%). Schematic.

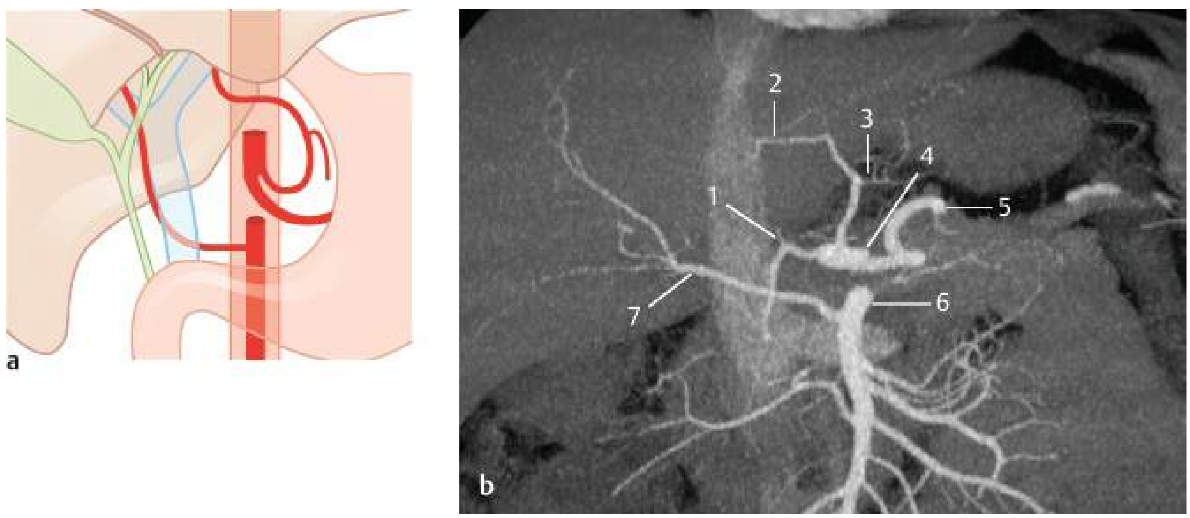

Fig. 14.15 Replaced right hepatic artery from the superior mesenteric and replaced left hepatic artery from the left gastric artery (<1%). Schematic (**a**) and coronal MIP CT (**b**). **1** Gastroduodenal artery; **2** left hepatic artery; **3** left gastric artery; **4** celiac trunk; **5** splenic artery; **6** superior mesenteric artery; **7** right hepatic artery.

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15 Cystic Artery

K.I. Ringe, S. Meyer

The cystic artery normally divides into a superficial branch to supply the anterior side of the gallbladder and a deep branch which supplies the part of the gallbladder adjacent to the liver. This division is usually at the border between the neck and the body of the gallbladder, but in rare cases it is more proximal, occurring as a “high division.” The deep branch generally also supplies parts of the liver with branches which are sometimes surprisingly large and probably play an important role in the arterial blood supply of the liver.

Data on the frequency of two cystic arteries vary considerably. The reason for this discrepancy might be that the deep branch often leaves the right hepatic artery near the liver and can be easily overlooked. If there are two cystic arteries, one artery is nearly always a branch of the right hepatic artery.

About three-fourth of all cystic arteries originate in Calot's triangle, which is formed by the cystic duct, the common hepatic duct, and the liver.[1] The remaining one-fourth crosses the biliary ducts, usually at the common hepatic duct or less frequently at the choledochus or right hepatic duct. These arteries normally cross in front of the biliary ducts similar to the surgeon's path of access to this area. If there are two separate cystic arteries, the crossing of the ducts is quite common. If the surgeon detects a cystic artery which crosses the biliary ducts, he or she should also look for a second cystic artery in Calot's triangle.[2–6]

15.1 One Cystic Artery (80%)

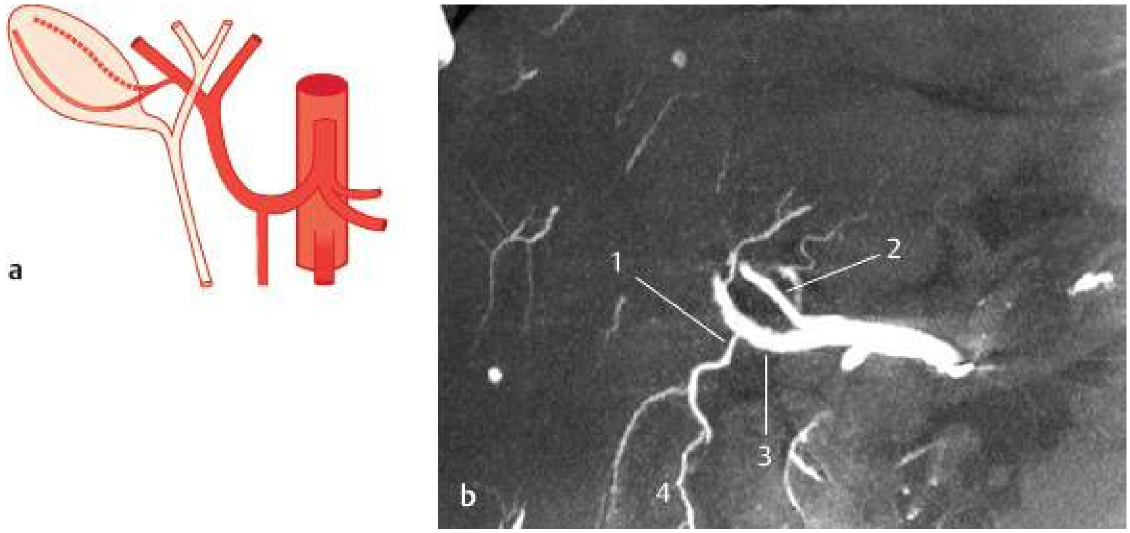

Fig. 15.1 Cystic artery as a branch of the right hepatic artery (46%). Schematic (**a**) and coronal MIP CT (**b**). **1** Cystic artery; **2** left hepatic artery; **3** right hepatic artery; **4** gallbladder.

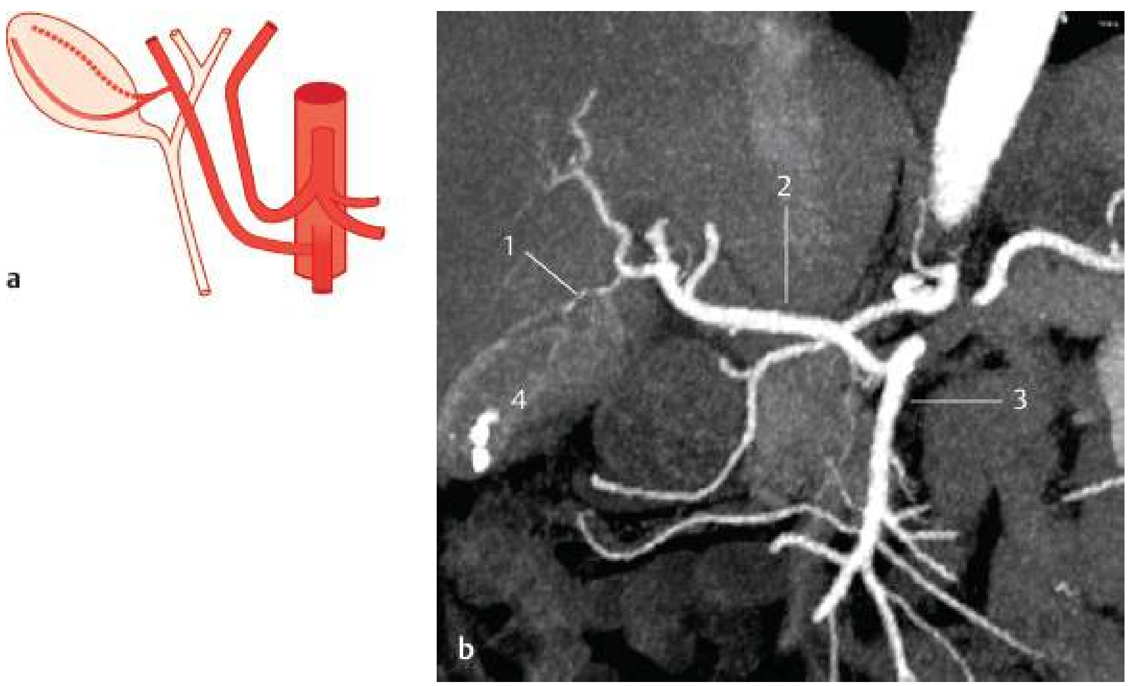

Fig. 15.2 Cystic artery as a branch of an accessory right hepatic artery which originates from the superior mesenteric artery (12%). Schematic (**a**) and coronal oblique MIP CT (**b**) (patient with gallstones). **1** Cystic artery; **2** right hepatic artery; **3** superior

mesenteric artery; **4** gallbladder with gallstones.

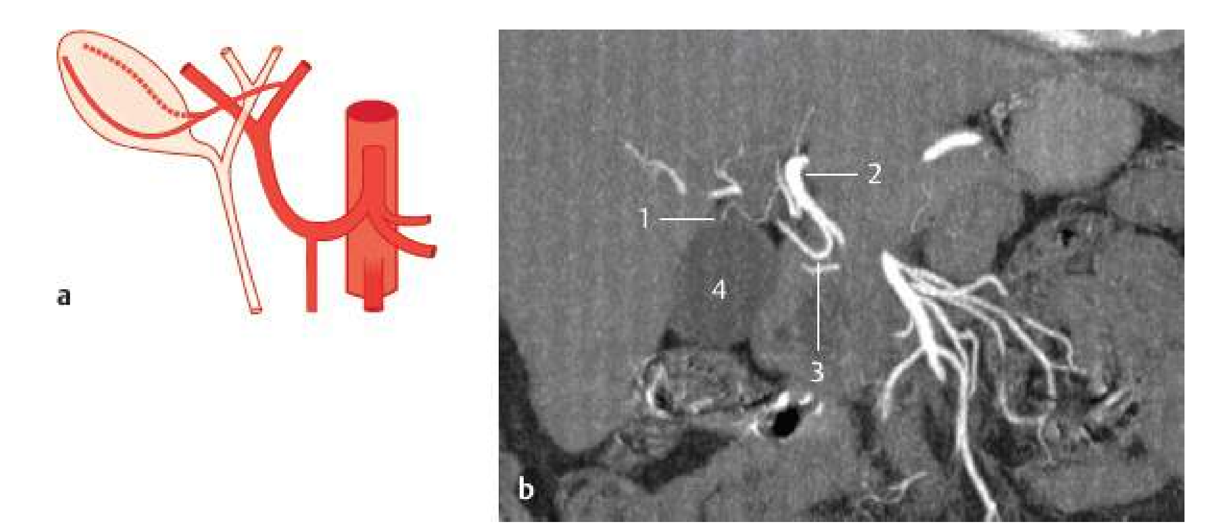

Fig. 15.3 Cystic artery as a branch of the left hepatic artery (5%). Schematic (**a**) and coronal MIP CT (**b**). **1** Cystic artery; **2** left hepatic artery; **3** right hepatic artery **4** gallbladder.

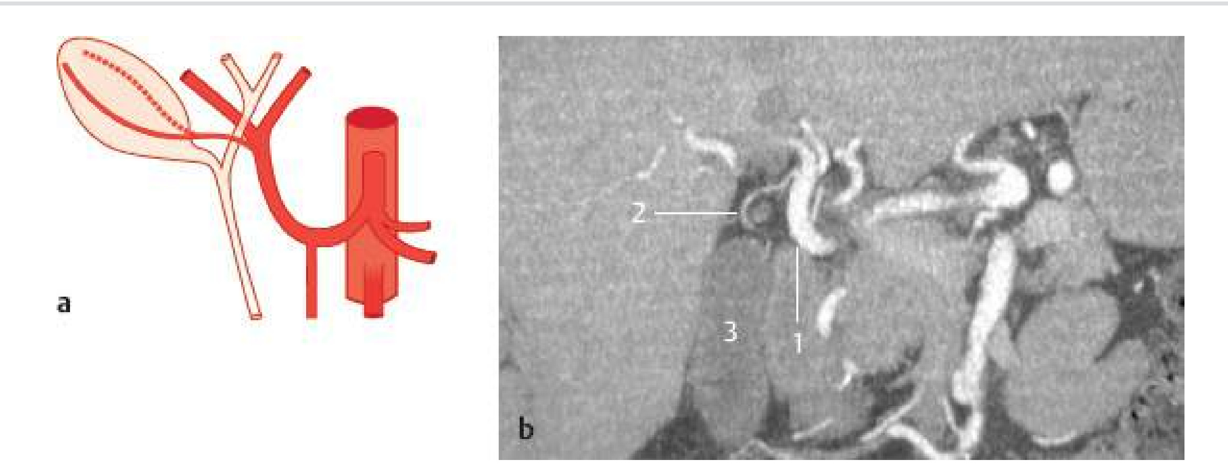

Fig. 15.4 Cystic artery originates from the bifurcation of the common hepatic artery (10%). Schematic (**a**) and coronal MIP CT (**b**). **1** Common hepatic artery; **2** cystic artery; **3** gallbladder.

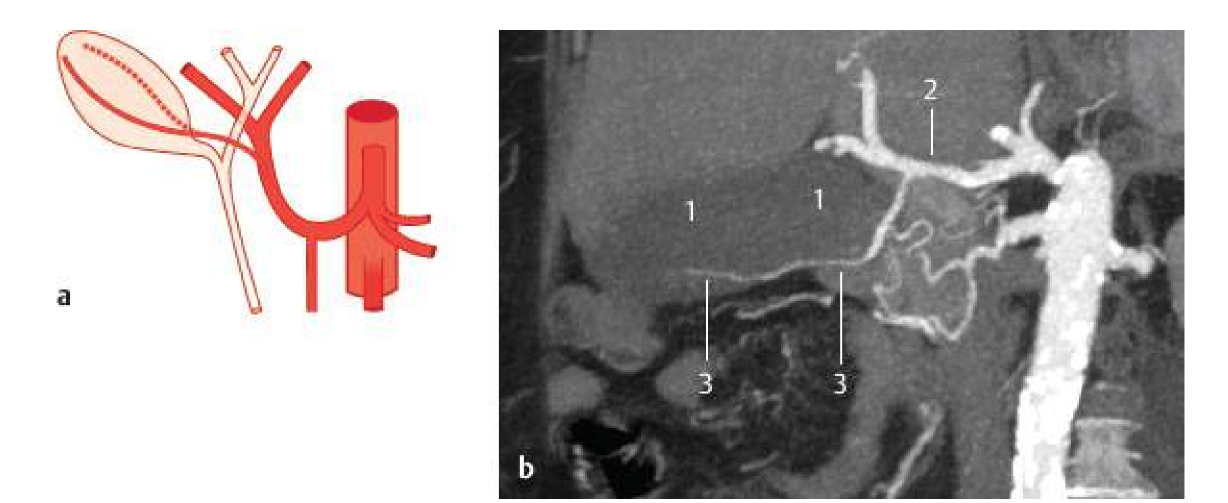

Fig. 15.5 Cystic artery originates from the proper hepatic artery or very rarely from the right gastric artery (2%). Schematic (**a**) and coronal MIP CT (**b**) showing one cystic artery originating from the proper hepatic artery. **1** Gallbladder; **2** proper hepatic artery; **3** cystic artery.

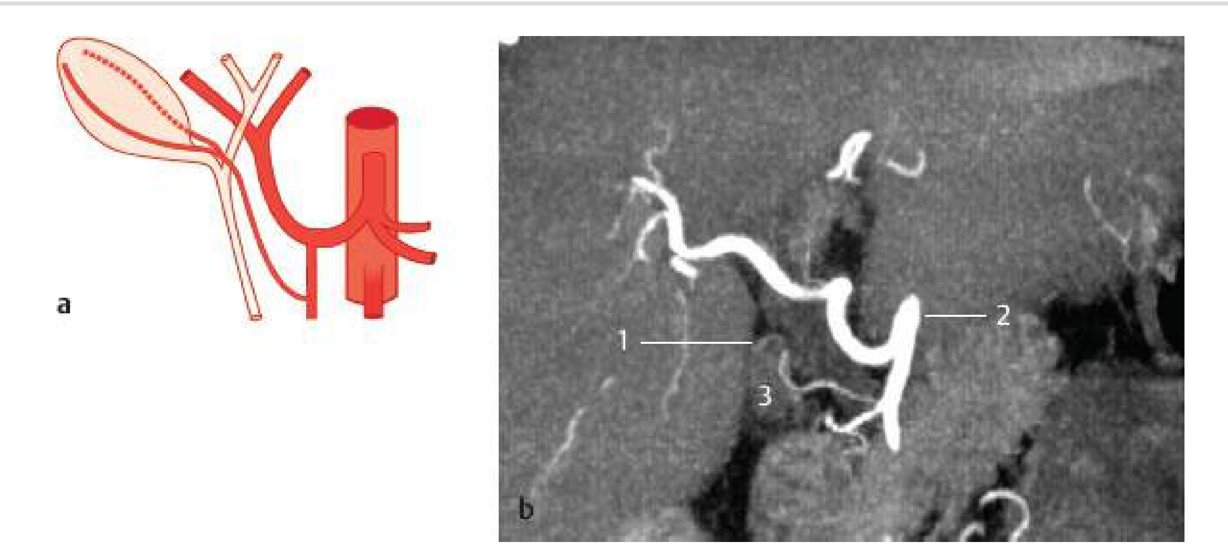

Fig. 15.6 Cystic artery arises from the gastroduodenal artery or one of its branches (2%). Schematic (**a**) and coronal MIP CT (**b**) showing one cystic artery originating from the gastroduodenal artery. **1** Cystic artery; **2** gastroduodenal artery; **3** gallbladder.

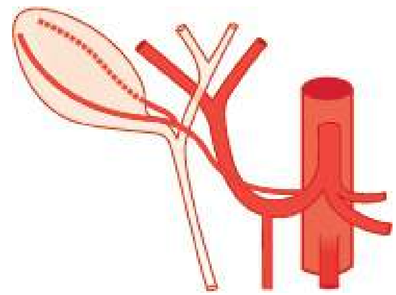

Fig. 15.7 Cystic artery originates from the common hepatic artery (2%). Schematic.

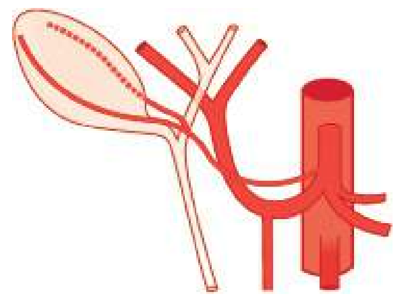

Fig. 15.8 Cystic artery arises from the celiac trunk (<1%). Schematic.

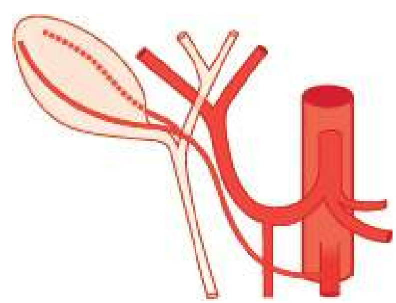

Fig. 15.9 Cystic artery as a branch of the superior mesenteric artery (<1%). Schematic.

15.2 Two Cystic Arteries (20%)

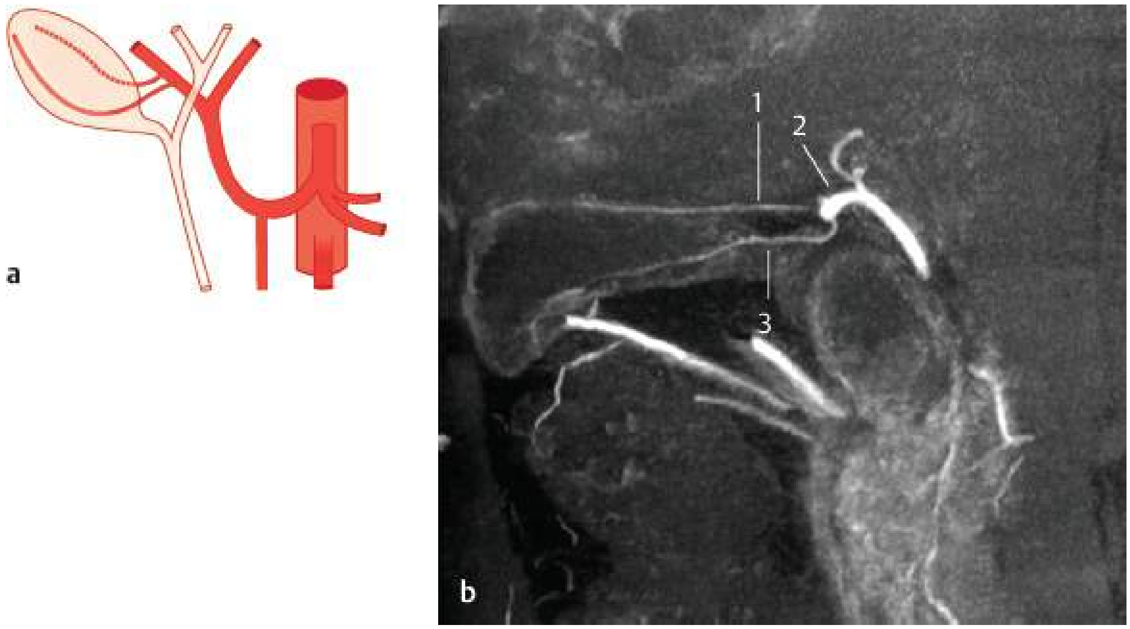

Fig. 15.10 Both cystic arteries originate from the right hepatic artery (13%). In one-third of all cases, the right hepatic artery is a branch of the superior mesenteric artery. Schematic (**a**) and coronal oblique MIP CT (**b**). **1** Cystic artery 1; **2** right hepatic artery; **3** cystic artery 2.

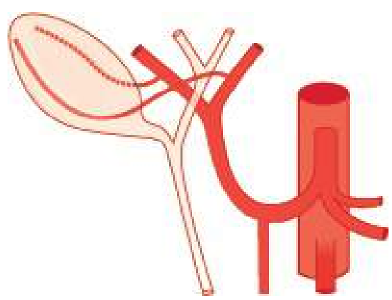

Fig. 15.11 One cystic artery arises from the right hepatic, one from the left hepatic artery (2%). Schematic.

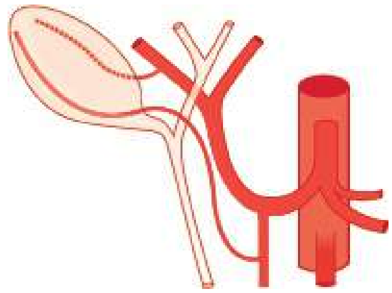

Fig. 15.12 One cystic artery originates from the right hepatic, one from the gastroduodenal artery (3%). Schematic.

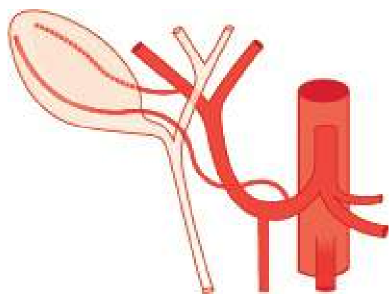

Fig. 15.13 One cystic artery arises from the right hepatic, one from the common hepatic artery (1%). Schematic.

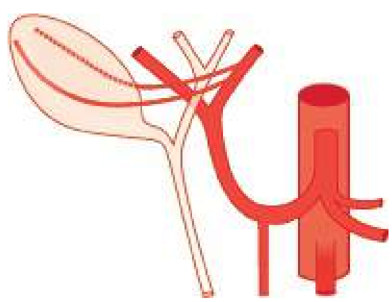

Fig. 15.14 Both cystic arteries branch from the left hepatic artery (<1%). Schematic.

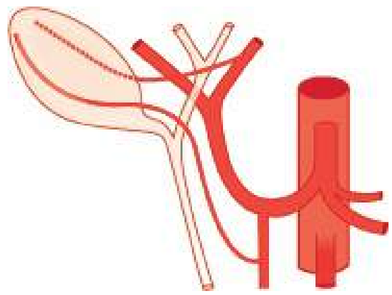

Fig. 15.15 One cystic artery originates from the left hepatic artery, the other from the gastroduodenal artery or one of its branches (<1%). Schematic.

15.3 Three or More Cystic Arteries (<1%)

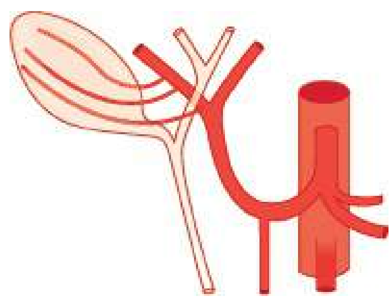

Fig. 15.16 Three cystic arteries (<1%). Schematic.

15.4 Topography of the Cystic Arteries

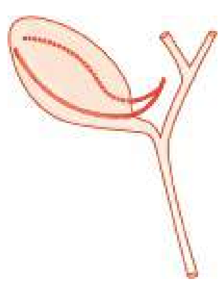

Fig. 15.17 Cystic artery originates in Calot's triangle (75%). Schematic.

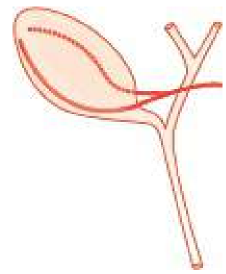

Fig. 15.18 Cystic artery crosses in front of the hepatic duct (22%). Schematic.

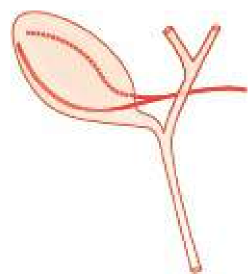

Fig. 15.19 Cystic artery crosses behind the hepatic duct (3%). Schematic.

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16 Splenic Artery

K.I. Ringe, S. Meyer

Along the course of the splenic artery from the celiac trunk, usually its largest branch, four subdivisions are apparent: suprapancreatic, pancreatic, prepancreatic, and prehilar parts. The second segment, the pancreatic part, is suprapancreatic in approximately 90%, behind the pancreas in 8%, and in front of the pancreas in 2% of all cases. The splenic artery is characterized by a tortuosity which can equal a length of up to 50 cm, although the distance from the aorta to the spleen is only approximately 10 cm.[1–9]

The origin from the celiac trunk and its variability are shown in Chapter 13. In the majority of cases, the splenic artery divides into at least two main branches at some distance from the spleen—"distributed type"; the other alternative branches near to the splenic parenchyma—"magistral type." Six to thirty-six individual arteries enter the spleen without major anastomoses within the spleen. These arteries supply the segment like parts of the spleen, and are of great clinical importance in partial splenectomies, which are preferred nowadays to a total splenectomy.[4,5,10]

16.1 Type of Branching

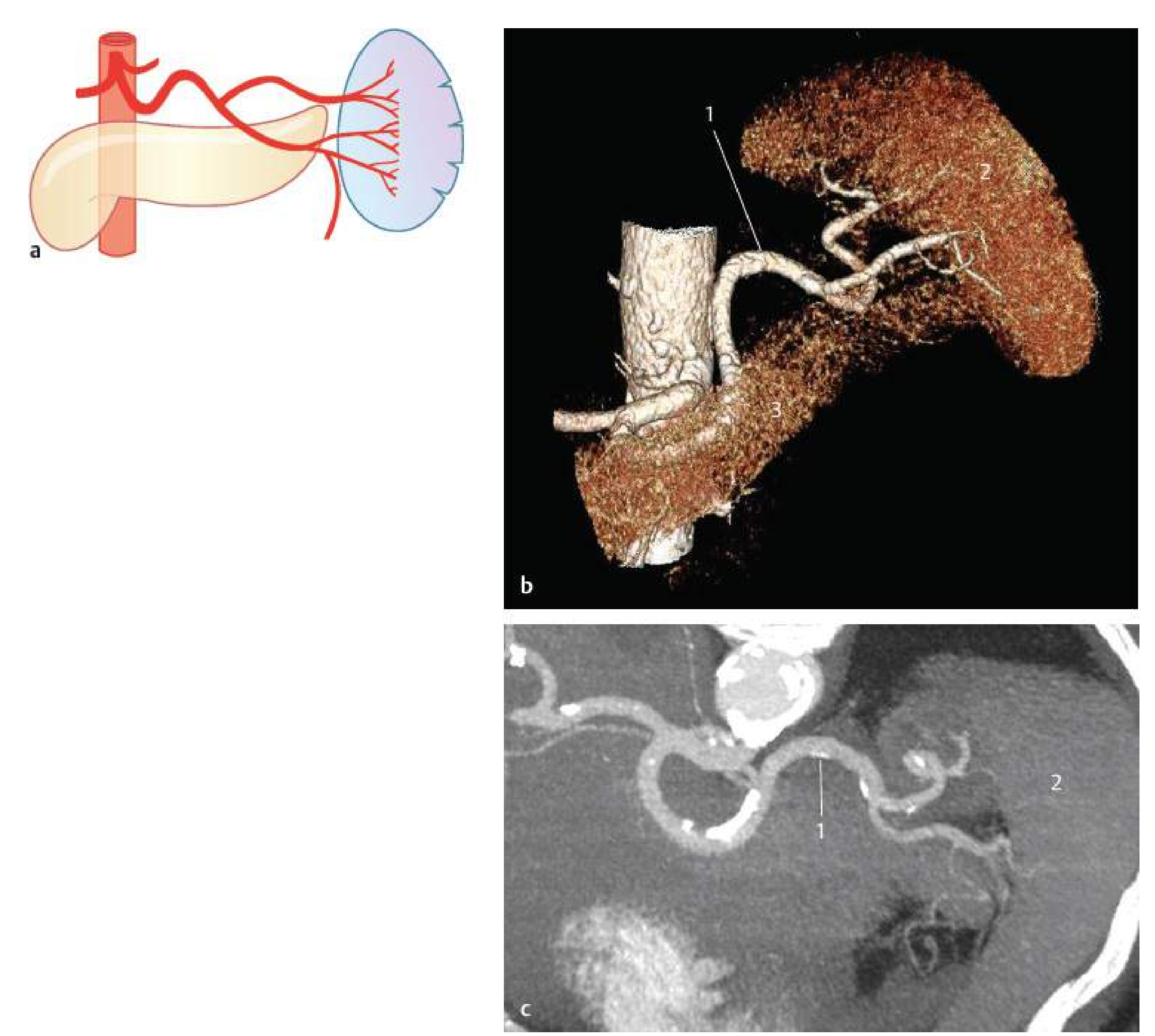

Fig. 16.1 Remote from the hilus (distributed type) (70%). Schematic (**a**), coronal VR CT (**b**), and axial MIP CT (**c**). **1** Splenic artery; **2** spleen; **3** pancreas.

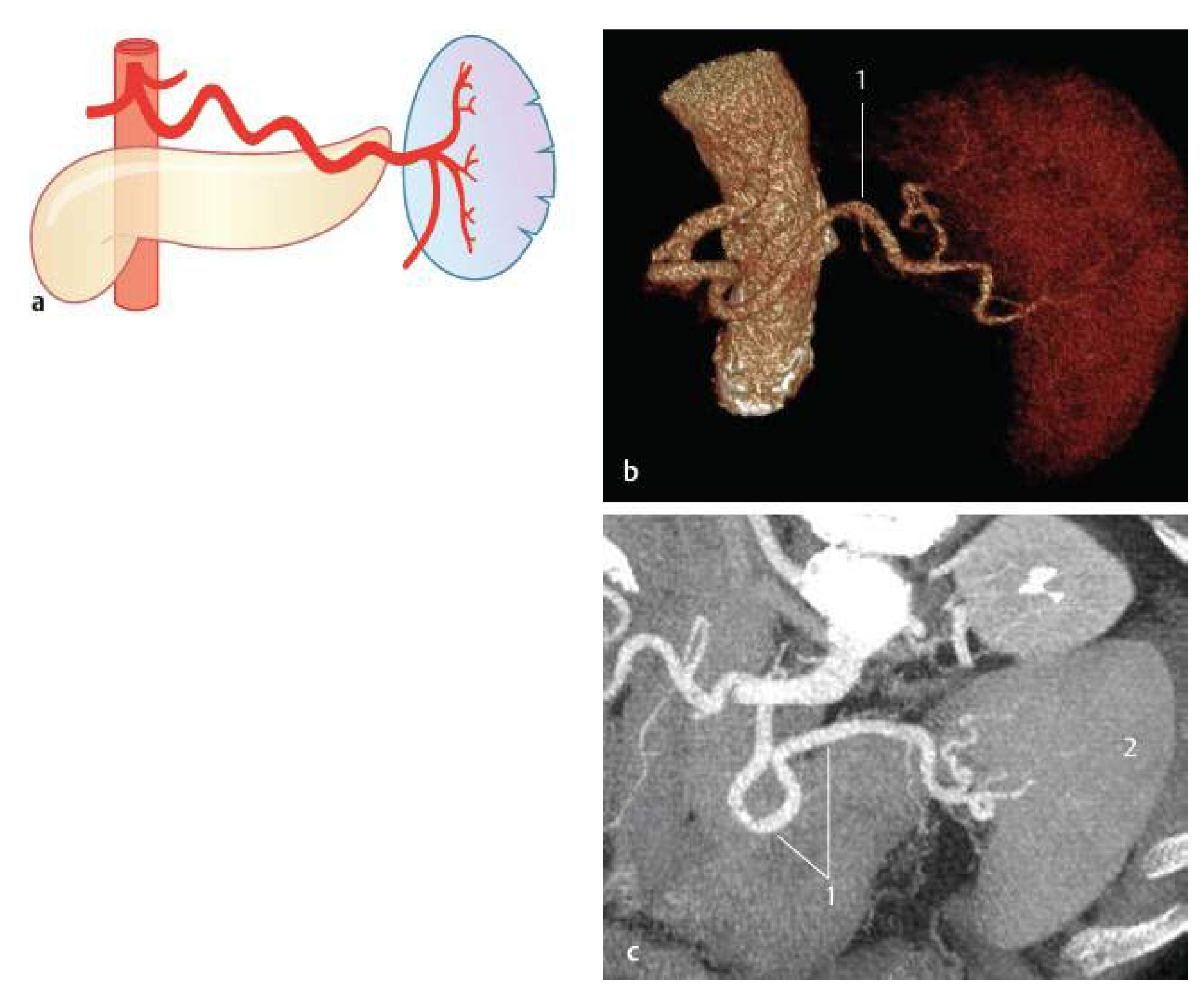

Fig. 16.2 Near the hilus (magistral type) (30%). Schematic (**a**), coronal VR CT (**b**), and axial oblique MIP CT (**c**). **1** Splenic artery; **2** spleen.

16.2 Polar Arteries

Important branches of the splenic artery are the short gastric arteries and the left gastroepiploic artery (see gastric arteries, Chapter 17). Arteries to the cranial or caudal pole of the spleen originate from the main splenic artery or the superior or inferior terminal branches. In rare instances, the upper polar arteries arise from the aorta, the left gastric artery, a pancreatic artery, or even a mesenteric artery.[2,11]

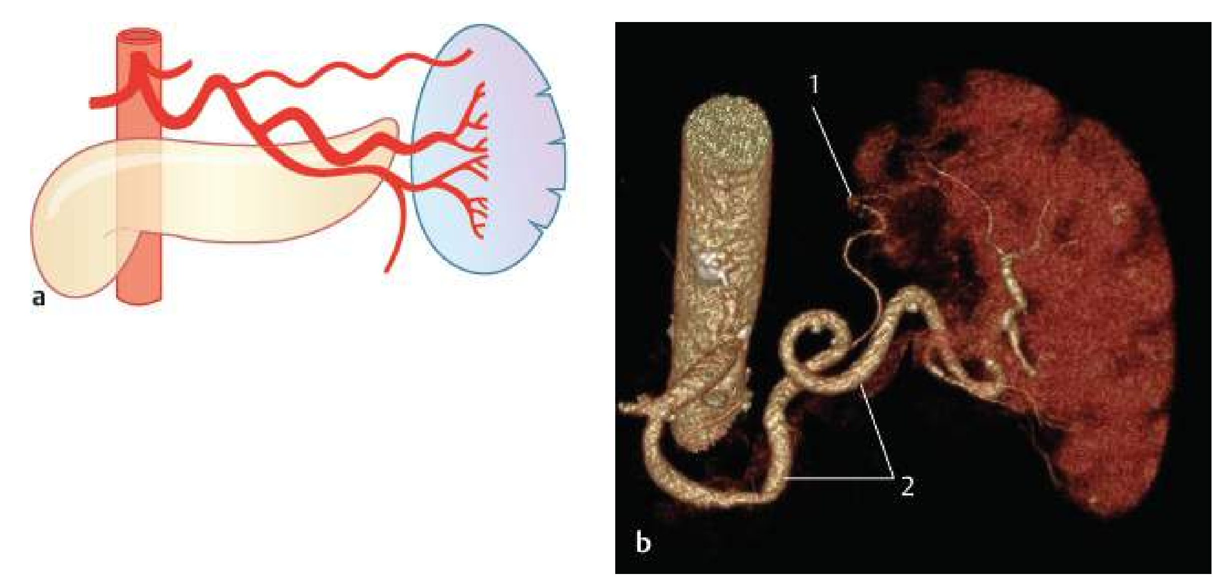

Fig. 16.3 Upper polar artery (65%). Schematic (**a**) and coronal VR CT (**b**). **1** Upper polar artery; **2** splenic artery.

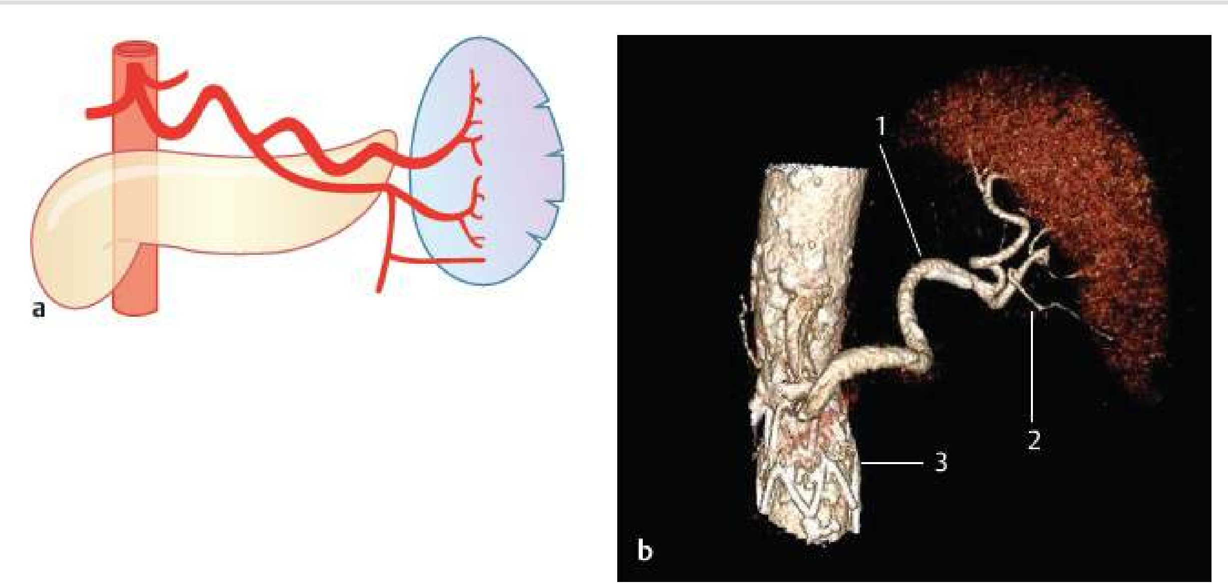

Fig. 16.4 Lower polar artery (80%). Schematic (**a**) and coronal VR CT (**b**). The patient has an abdominal aortic prosthesis. **1** Splenic artery; **2** lower polar artery; **3** abdominal aortic prosthesis.

16.3 Position of the Splenic Artery

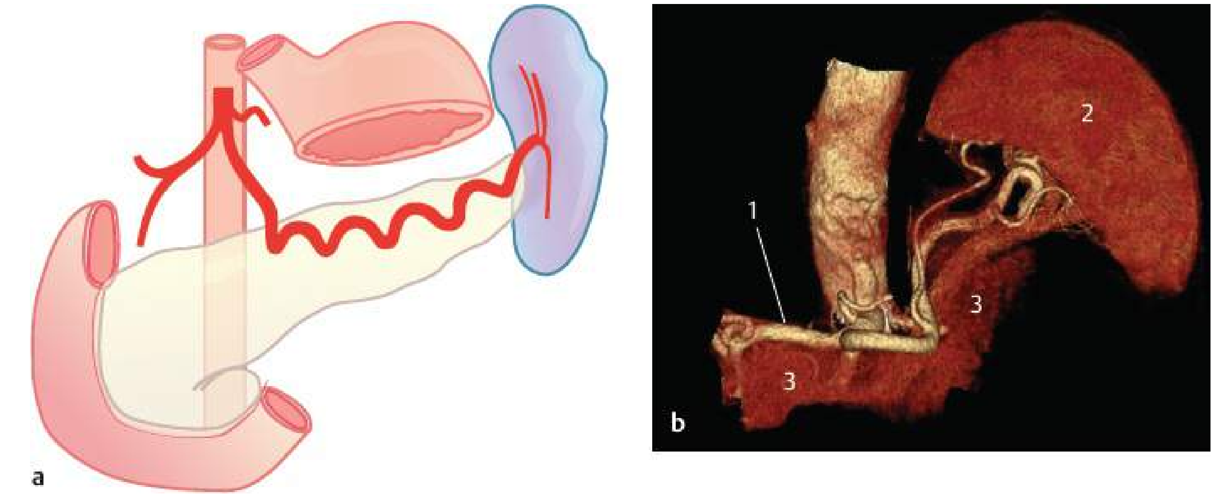

Fig. 16.5 Along the upper border of the pancreas (suprapancreatic) (90%). Schematic (**a**) and coronal VR CT (**b**). **1** Splenic artery; **2** spleen; **3** pancreas.

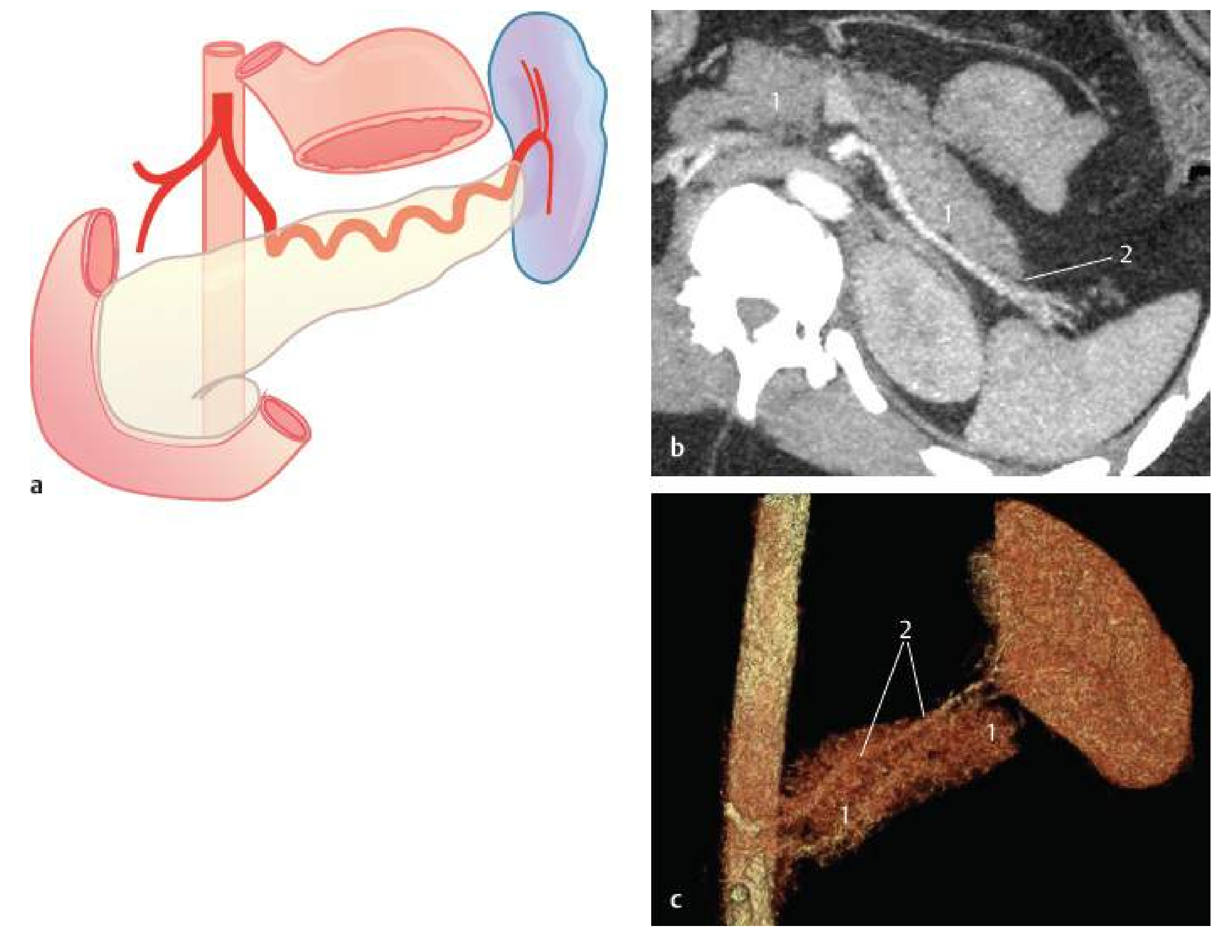

Fig. 16.6 Behind the pancreas (retropancreatic) (8%). Schematic (**a**), axial MIP CT (**b**), and coronal VR CT (**c**). **1** Pancreas; **2** splenic artery.

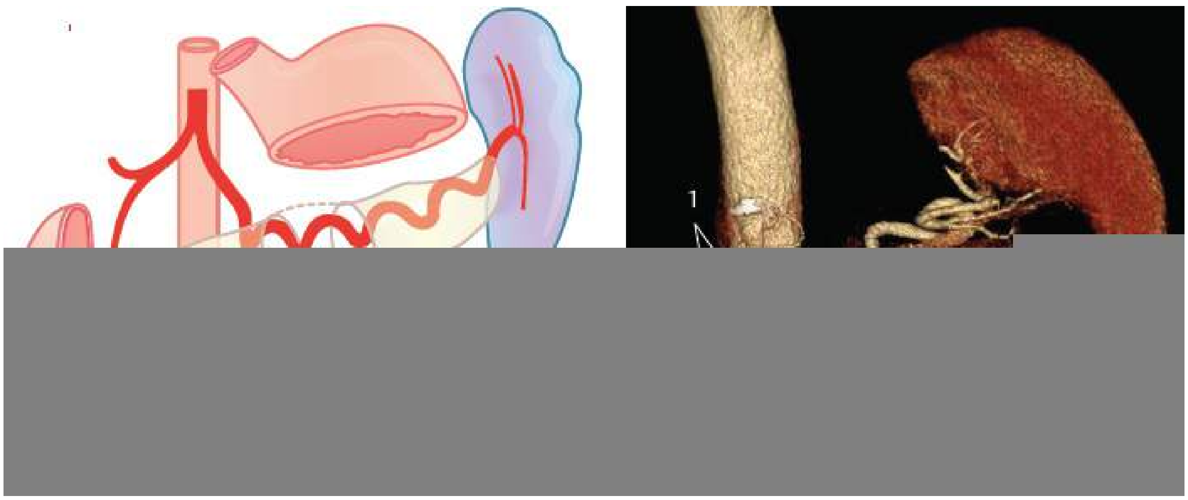

Fig. 16.7 Within the pancreas (intrapancreatic) (2%). Schematic (**a**) and coronal VR CT (**b**). **1** Splenic artery; **2** pancreas.

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17 Gastric Arteries

K.I. Ringe, S. Meyer

Textbooks usually list six arteries for the stomach and outline them in figures. The left and right gastric arteries anastomose along the lesser curvature. The left and right gastroepiploic arteries are found along the greater curvature. The fundus of the stomach is supplied by the short gastric arteries, which vary in number, and the pyloric region, by the gastroduodenal artery. The arterial anastomoses at the cardioesophageal (see esophageal arteries, Chapter 5) and at the gastroduodenal end of the stomach are extremely variable. In most cases, the left gastric artery is more prominent than the right.

17.1 “Normal” Blood Supply of the Stomach

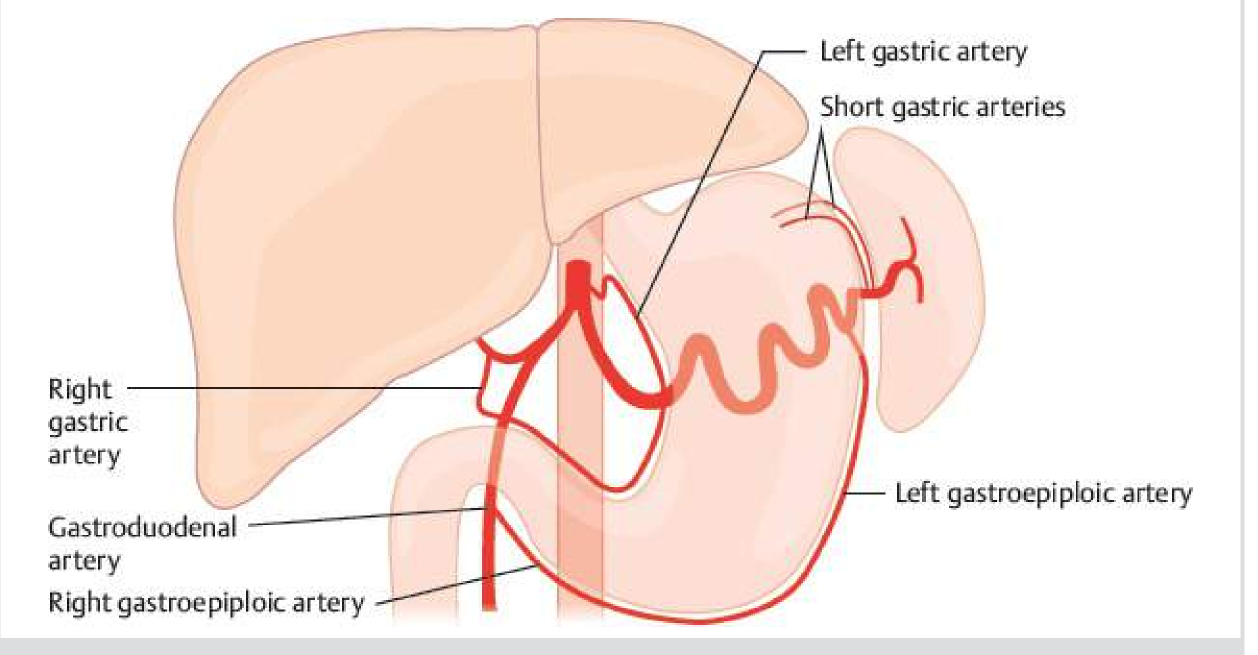

Fig. 17.1 “Normal” blood supply of the stomach. Schematic.

17.2 Right Gastric Artery

At the greater curvature, the right gastroepiploic artery is nearly always larger than the left, and the right gastroepiploic artery usually ends beyond the midline of the lower border.[1–14]

Fig. 17.2 "Normal" situation, origin from the common hepatic artery (~50%). Schematic (**a**) and coronal MIP CT (**b**). **1** Right gastric artery; **2** stomach; **3** common hepatic artery.

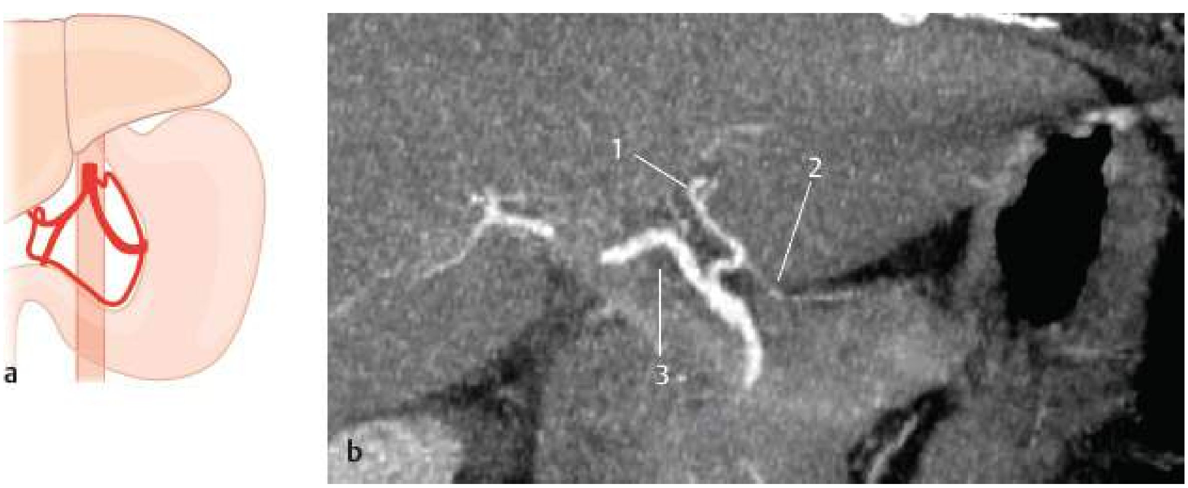

Fig. 17.3 Origin from the left hepatic artery (15%). Schematic (**a**)

and coronal MIP CT (**b**). **1** Left hepatic artery; **2** right gastric artery; **3** right hepatic artery.

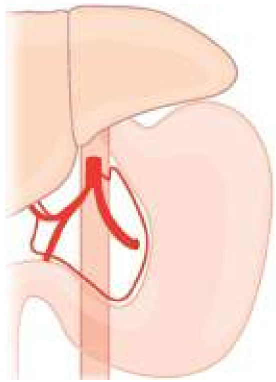

Fig. 17.4 Origin from the right hepatic artery (5%). Schematic.

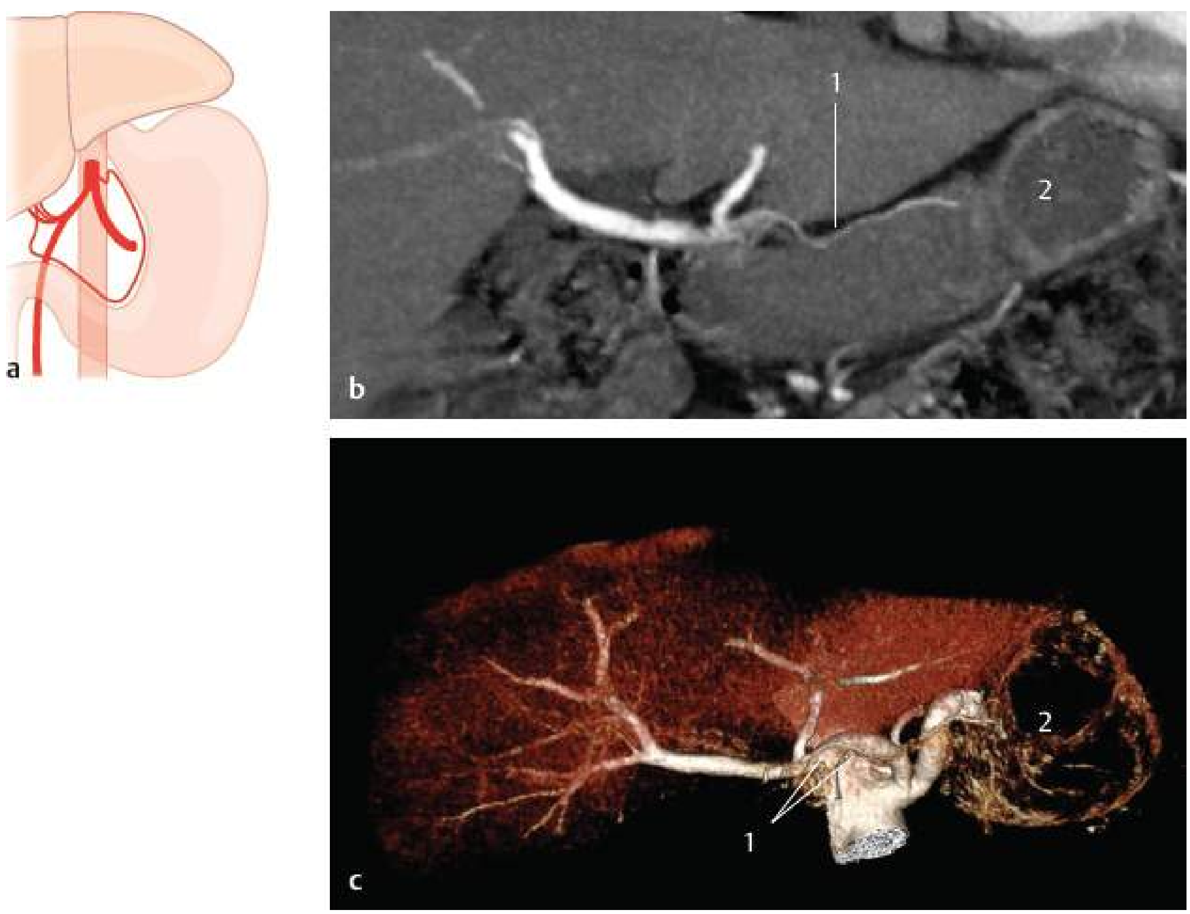

Fig. 17.5 Origin from a middle hepatic artery or at the bifurcation

of the proper hepatic artery (20%). Schematic (**a**) and CT images (**b,c**). Coronal VR (**b**) and MIP (**c**); the right gastric artery originates from the bifurcation of the proper hepatic artery. **1** Right gastric artery; **2** stomach.

17.3 Left Gastric Artery

The left gastric artery arises in approximately 90% of all cases from the celiac trunk and is usually the first branch. It is of great importance that in about one of four patients the left gastric artery participates in the blood supply of the liver, and in half of these cases it is an accessory hepatic but in the other half (11.5%) a replaced hepatic artery. The left gastric artery usually divides into two main branches, anterior and posterior.[1,3,4,7,15,16] The right gastric artery anastomoses in most cases with the posterior branch of the left gastric artery.[1,3,7,17]

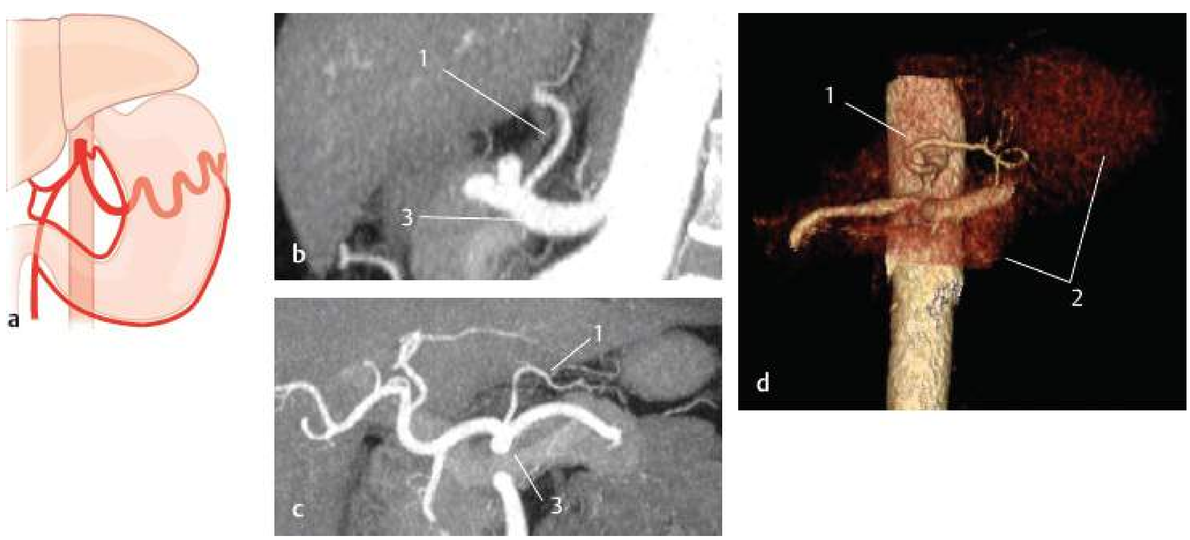

Fig. 17.6 "Normal" origin from the celiac trunk (~90%). Schematic (**a**), coronal VR CT (**b**), coronal MIP CT (**c**), and sagittal MIP (**d**). **1** Left gastric artery; **2** stomach; **3** celiac trunk.

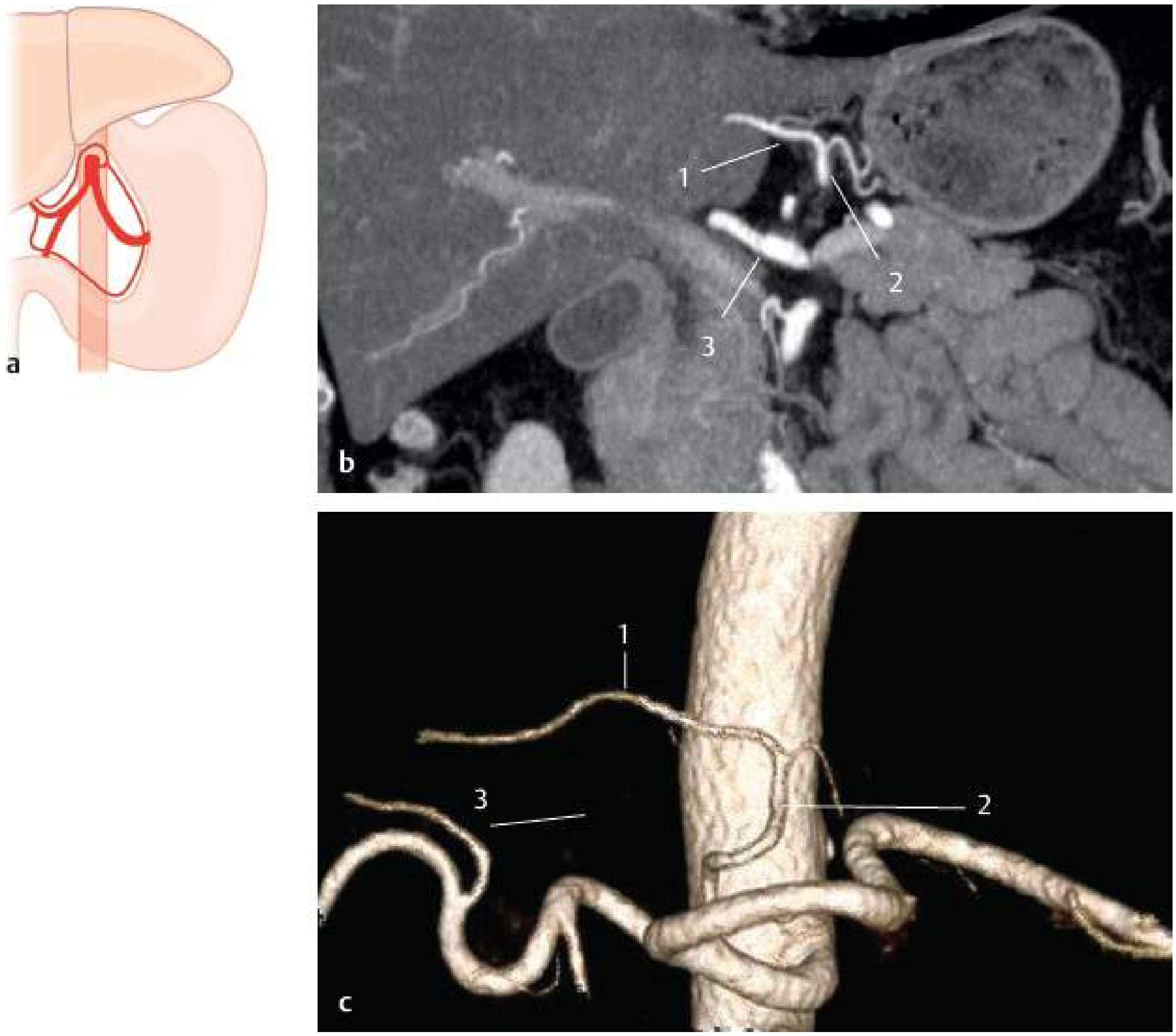

Fig. 17.7 An accessory hepatic artery arises from the left gastric artery (23%). Schematic (**a**), coronal MIP CT (**b**), and coronal VR CT (**c**). **1** Accessory hepatic artery; **2** left gastric artery; **3** hepatic artery.

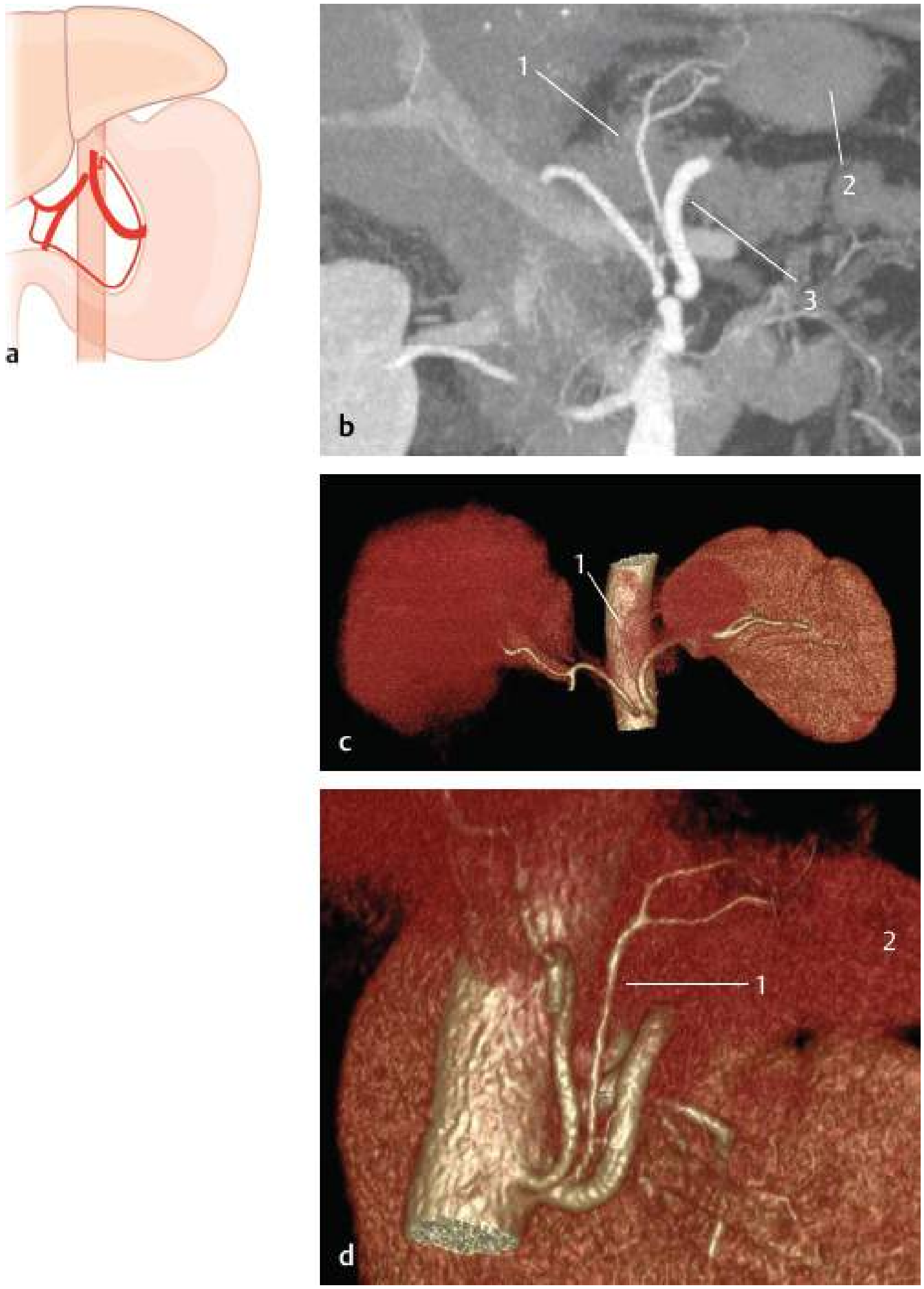

Fig. 17.8 Origin from a lienogastric trunk (4%). Schematic (**a**), coronal VR CT (**b**), coronal MIP CT (**c**), and sagittal VR CT (**d**). **1** Left gastric artery; **2** stomach; **3** splenic artery.

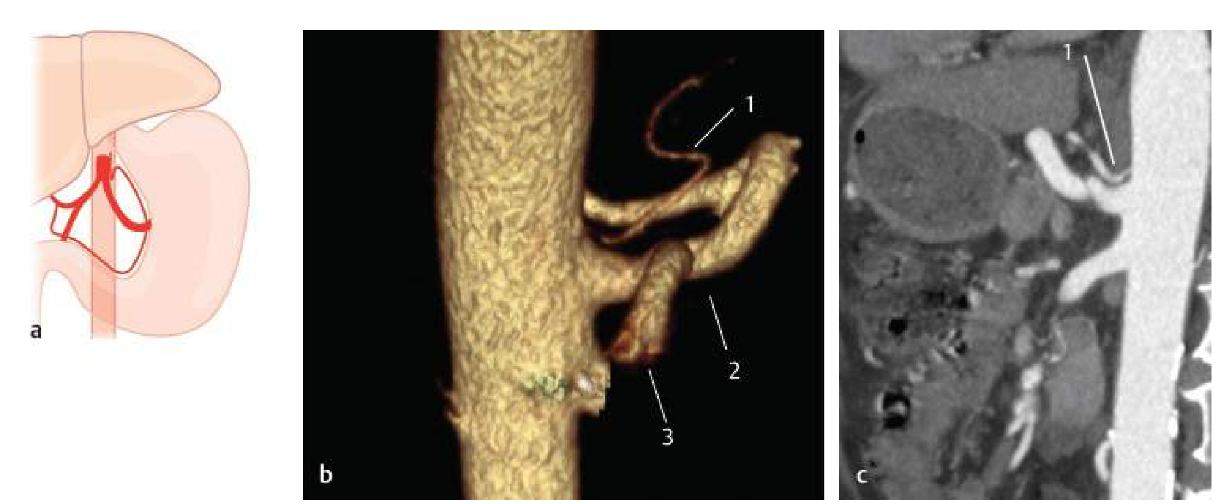

Fig. 17.9 Origin direct from the aorta (3%). Schematic (**a**), sagittal VR CT (**b**), and sagittal MIP CT (**c**). **1** Left gastric artery; **2** splenic artery; **3** hepatic artery.

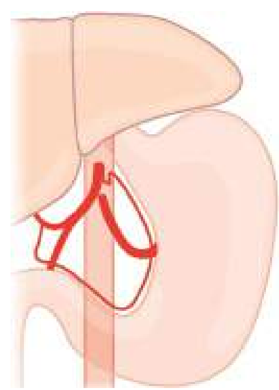

Fig. 17.10 Origin from a hepatogastric trunk (2%). Schematic.

17.4 Gastroepiploic Arteries

The left gastroepiploic artery is highly variable in origin, size, length, and number of branches. It generally originates from the splenic trunk or from an inferior splenic terminal, but sometimes from the superior terminal or even the interior of the spleen.[1,3,7] Of clinical importance is its origin, either directly or with other arteries, from the superior mesenteric artery.

The gastroepiploic arch can be near to the stomach wall or as far as 2 cm from the greater curvature.[1,3,7,18]

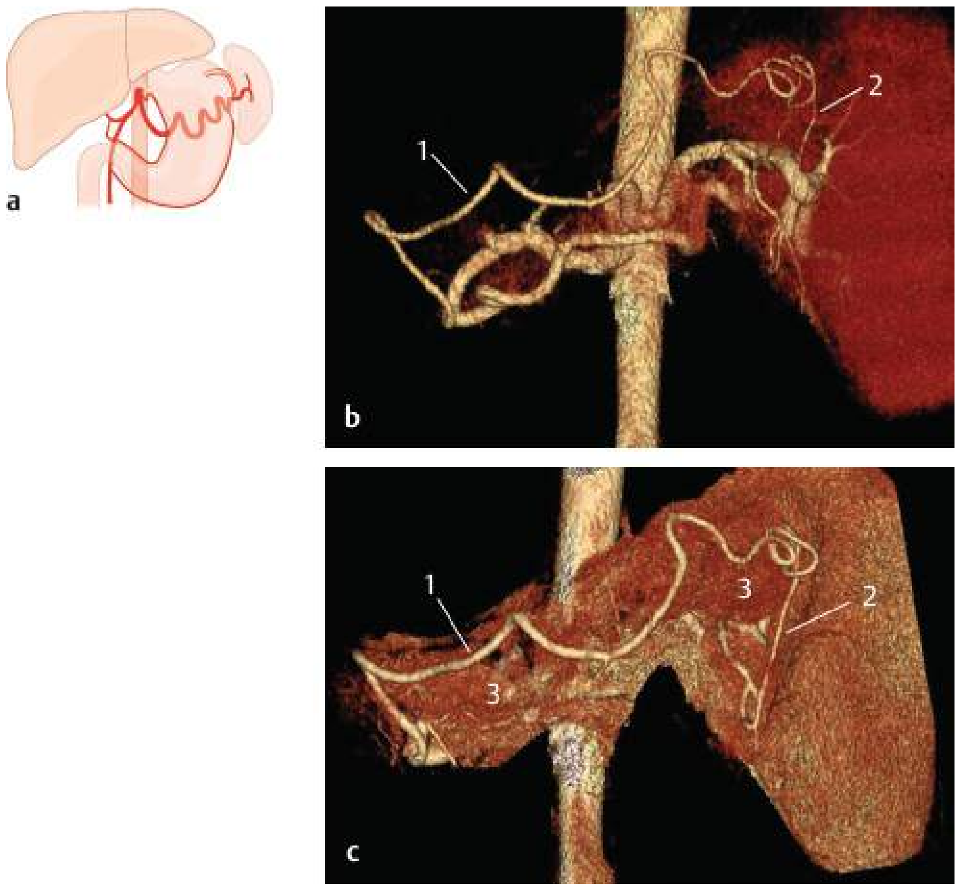

Fig. 17.11 “Normal” pattern with an anastomosis of the right and left gastroepiploic arteries (65%). Schematic (**a**) and coronal VR CT without (**b**) and with (**c**) stomach. **1** Right gastroepiploic artery; **2** left gastroepiploic artery; **3** stomach.

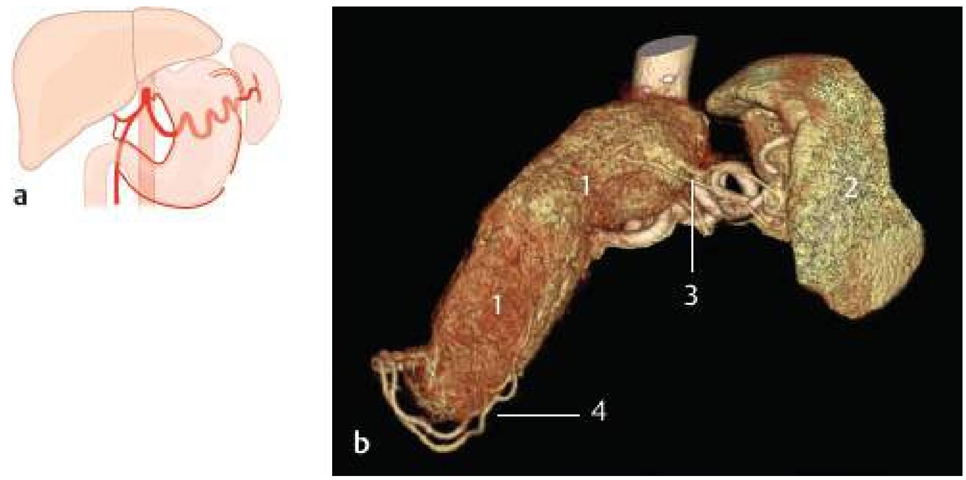

Fig. 17.12 No real anastomosis between the right and left gastroepiploic arteries (35%). Schematic (**a**) and coronal VR CT (**b**). **1** Stomach; **2** spleen; **3** left gastroepiploic artery; **4** right gastroepiploic artery.

17.5 A Posterior Gastric Artery Derives from the Splenic Artery (60%)

An artery that is not usually described is the posterior gastric artery, which arises from the splenic artery, ascends vertically or obliquely, and supplies the posterior wall, the fundus, and the cardiac region with adjacent parts of the esophagus. This artery has also been called an ascending posterior esophagogastric branch or accessory left gastric artery. The term posterior gastric artery should now be used since this name is included in the Nomina Anatomica (arteria gastrica posterior).[1,19,20]

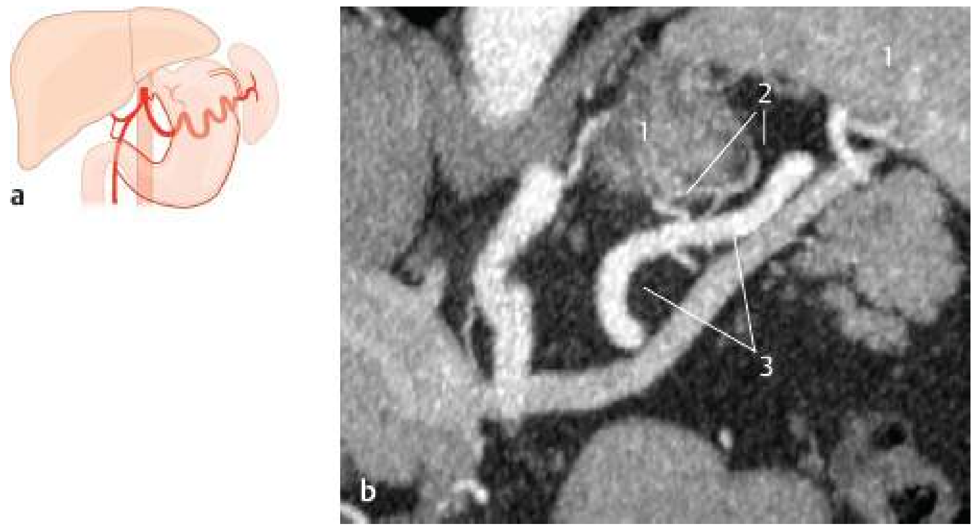

Fig. 17.13 A posterior gastric artery derives from the splenic artery (60%). Schematic (**a**) and coronal VR CT (**b**). **1** Stomach; **2** posterior gastric artery; **3** splenic artery.

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18 Pancreatic Arteries

K.I. Ringe, S. Meyer

The arterial supply of the pancreas is highly variable, but follows a general pattern.[1–22]

The head of the pancreas is supplied by anastomosing branches from the celiac trunk and the superior mesenteric artery. These arteries form arcades in front of and behind the head of the pancreas on the vertical axis.

The body of the pancreas is supplied by arteries running in the anterior and posterior arcades of the head of the pancreas; these arteries vary not only in number but also in origin. The anterior superior pancreaticoduodenal artery consistently represents the terminal branch of the gastroduodenal artery. Both inferior origins of the anterior and posterior arcades leave the superior mesenteric artery as a short common trunk (**Fig. 18.5**); alternative origins for the anterior arcade are shown in **Fig. 18.6, Fig. 18.7**, and **Fig. 18.8**.[23] The superior origin of the posterior arcade varies more often (**Fig. 18.11, Fig. 18.12, Fig. 18.13**, and **Fig. 18.14**). The transverse pancreatic artery to the body of the pancreas is connected with the posterior pancreatic and the large pancreatic arteries. The transverse pancreatic artery is often referred to as the inferior pancreatic artery or, less often, the superior pancreatic artery. This might partly explain the considerable discrepancy in the literature on the frequency of this artery. In addition to the origins shown in **Fig. 18.20, Fig. 18.21**, and **Fig. 18.22**, other origins, such as the common hepatic artery, the gastroduodenal artery, and the posterior arcade, have been described.

The cauda of the pancreas is supplied by numerous branches from the splenic artery,[5,20] which are not shown in the figures.

In selective pancreatic angiography, the number of arteries and branches identified largely depends on the position of the catheter and the direction of the blood flow in the different anastomosing arteries around or within the pancreas. Fewer pancreatic arteries are detected than in anatomical studies. The large pancreatic artery (arteria pancreatica magna) has not been depicted in detail in the figures in this chapter.

18.1 Pancreatic Arteries as Shown in Textbooks

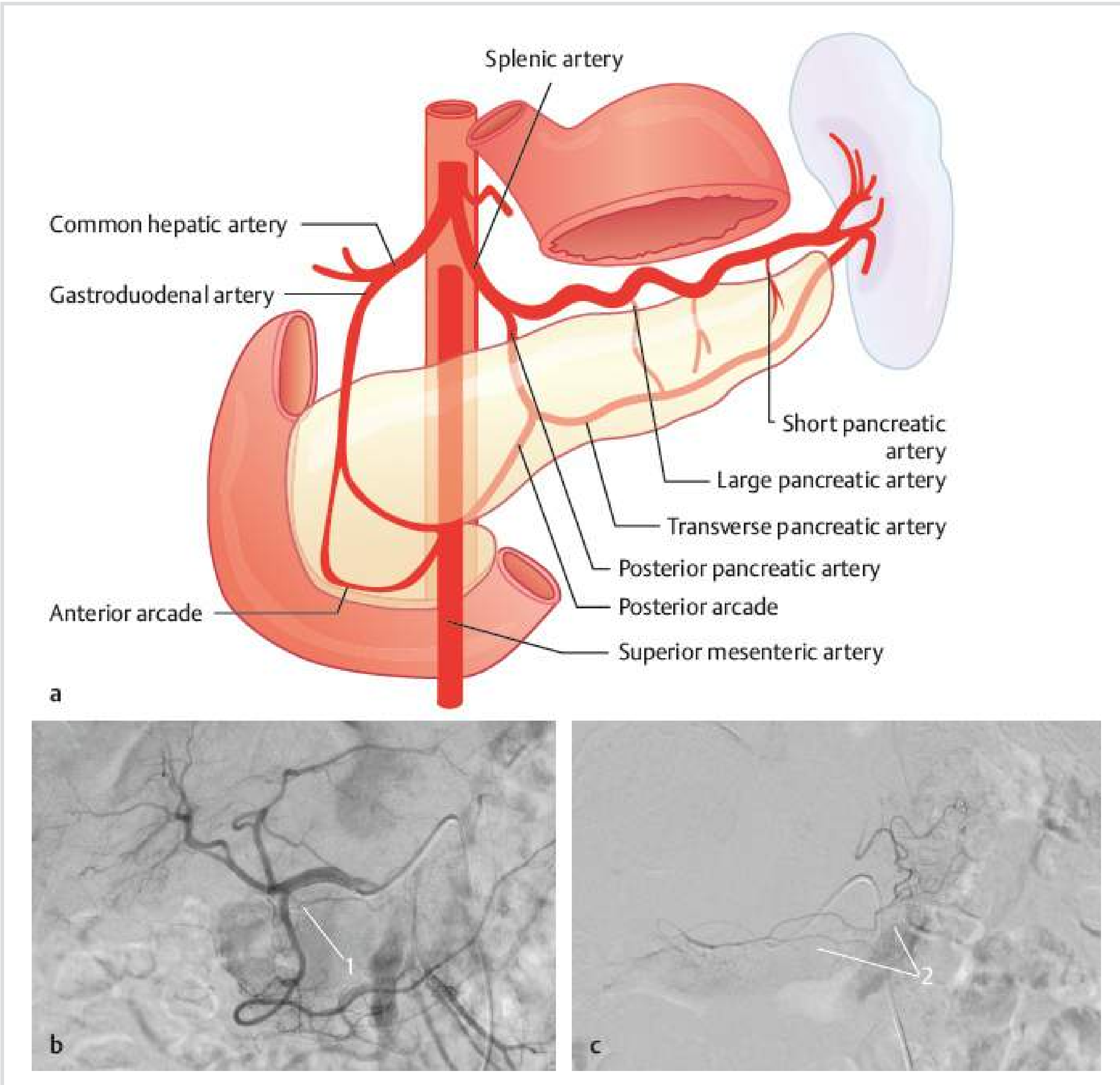

Fig. 18.1 **“Normal” blood supply of the pancreas**. Schematic (**a**) and angiography (**b,c**) with a catheter in the common hepatic artery (**b**) and a microcatheter in the anterior arcade (**c**). **1** Anterior arcade; **2** pancreas.

18.2 Number of Arterial Arcades in Front of the Head of the Pancreas

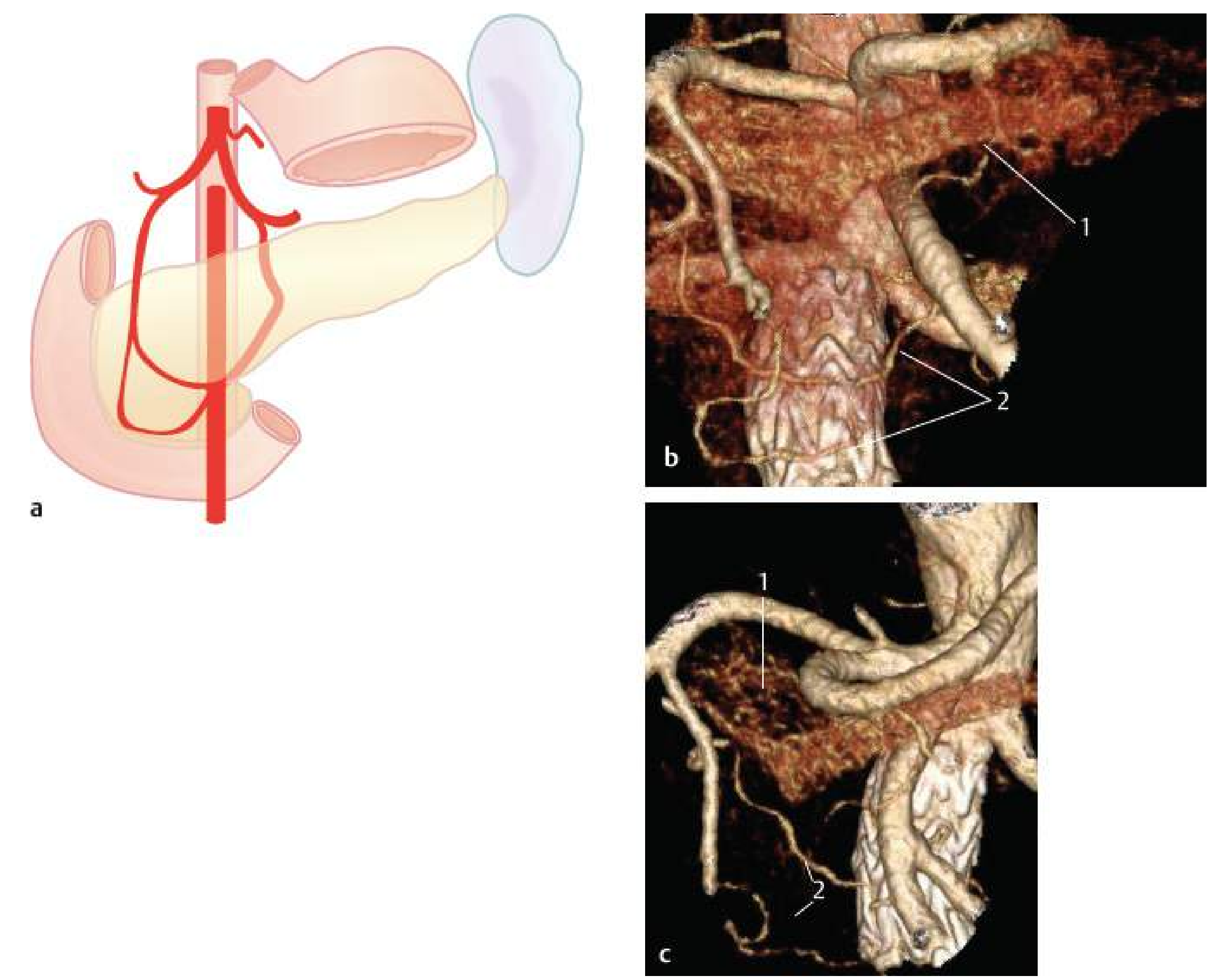

Fig. 18.2 Two arcades (79%). Schematic (**a**) and oblique VR CT, coronal (**b**) and sagittal (**c**) view. **1** Pancreas; **2** two arcades.

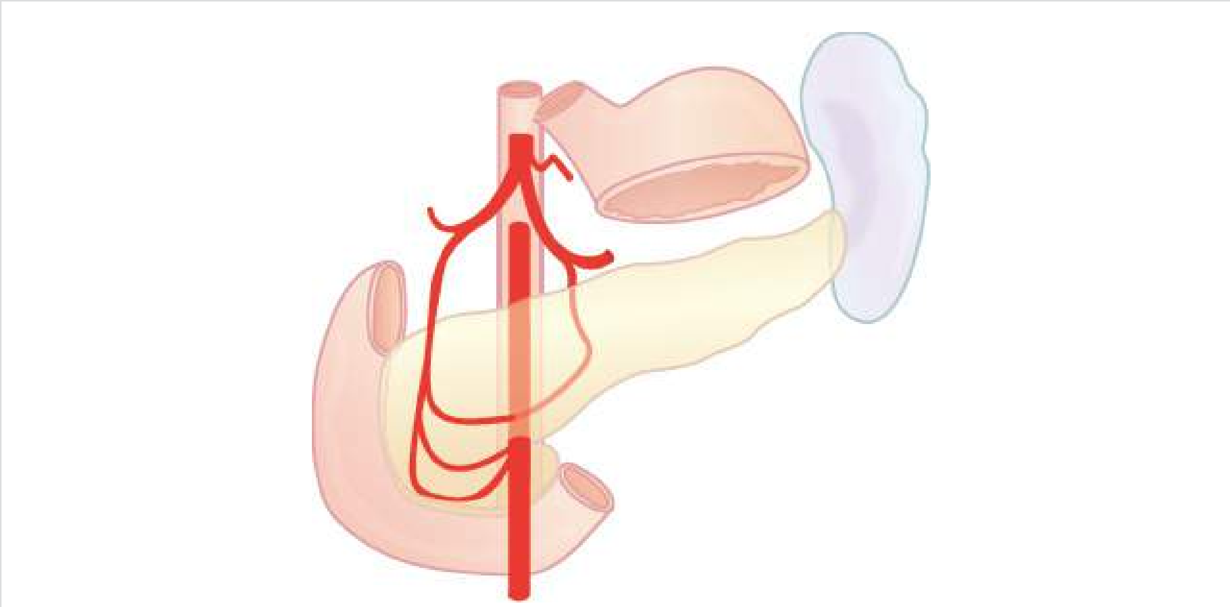

Fig. 18.3 Three arcades (16%). Schematic.

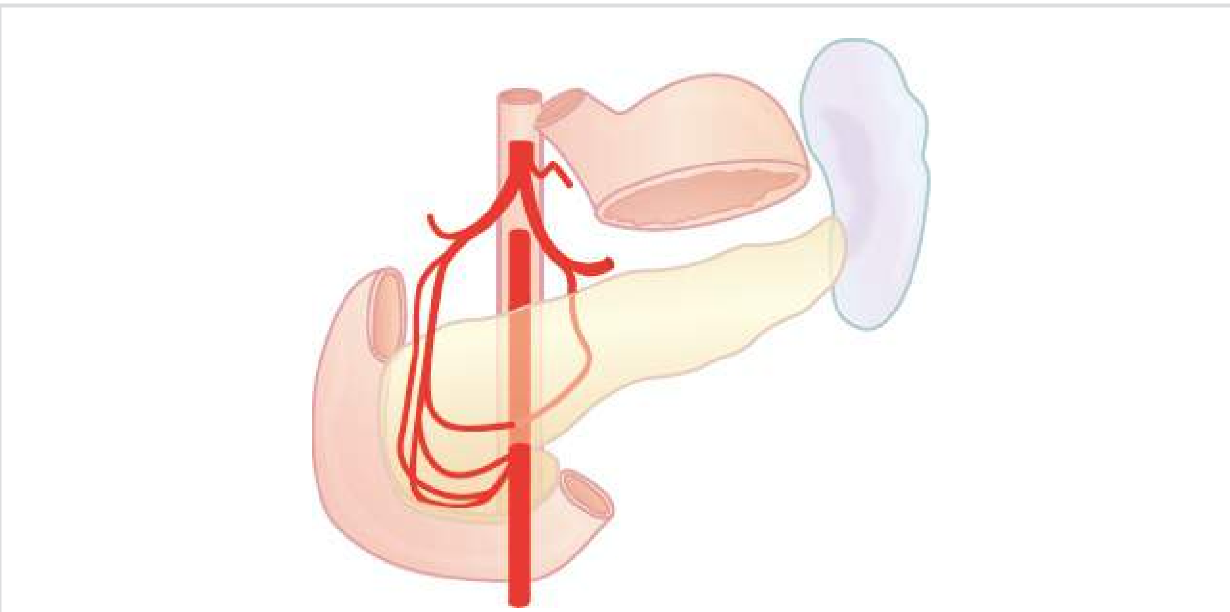

Fig. 18.4 Four arcades (5%). Schematic.

18.3 Inferior Origin of the Anterior Arcades

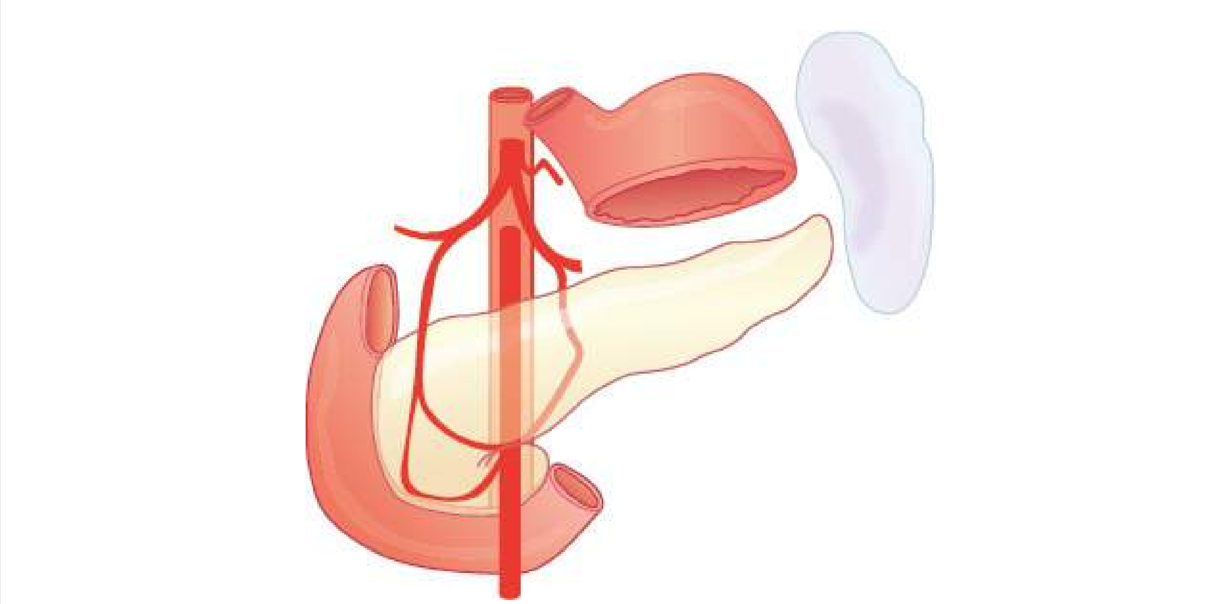

Fig. 18.5 Inferior origins of both the anterior and the posterior arcades leave the superior mesenteric artery as a short common trunk (65%). Schematic.

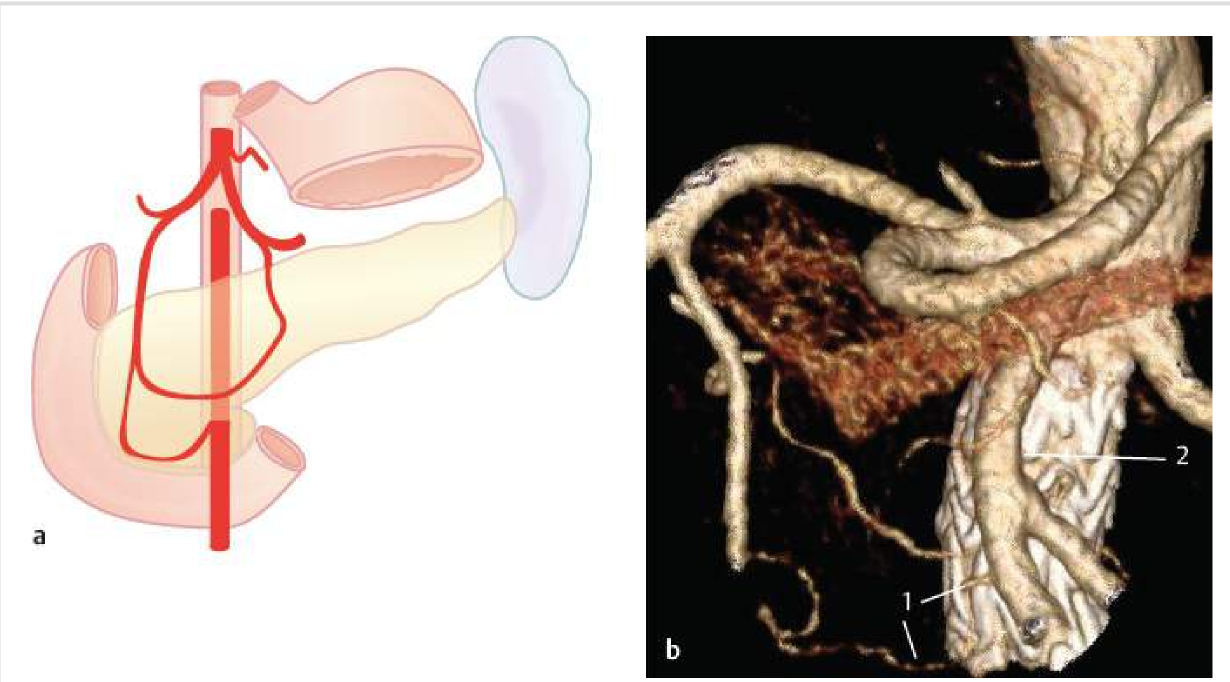

Fig. 18.6 Inferior origin from the right side of the stem of the superior mesenteric artery (8%). Schematic (**a**) and coronal VR CT (**b**). **1** Anterior arcade inferior origin; **2** superior mesenteric artery.

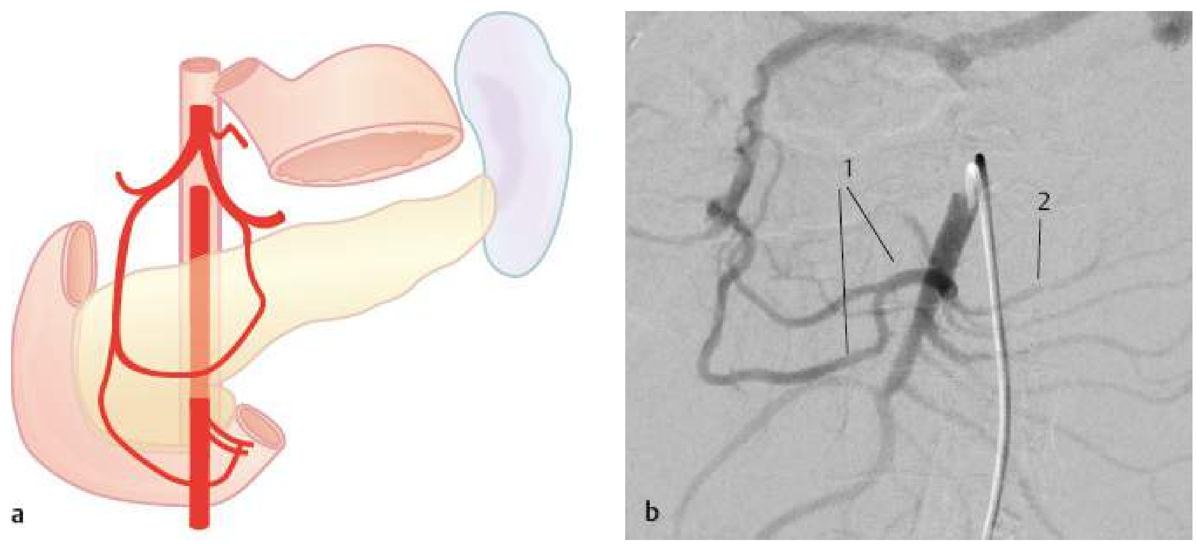

Fig. 18.7 Inferior origin from the first jejunal artery (15%). Schematic (**a**) and angiography (**b**) with a catheter in the superior mesenteric artery. **1** Anterior arcade; **2** first jejunal artery.

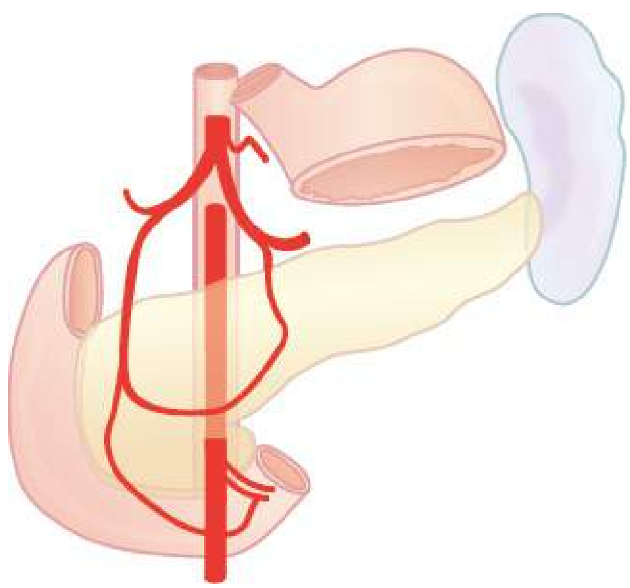

Fig. 18.8 Inferior origin from the second jejunal artery (2%). Schematic.

18.4 Number of Posterior Arterial Arcades

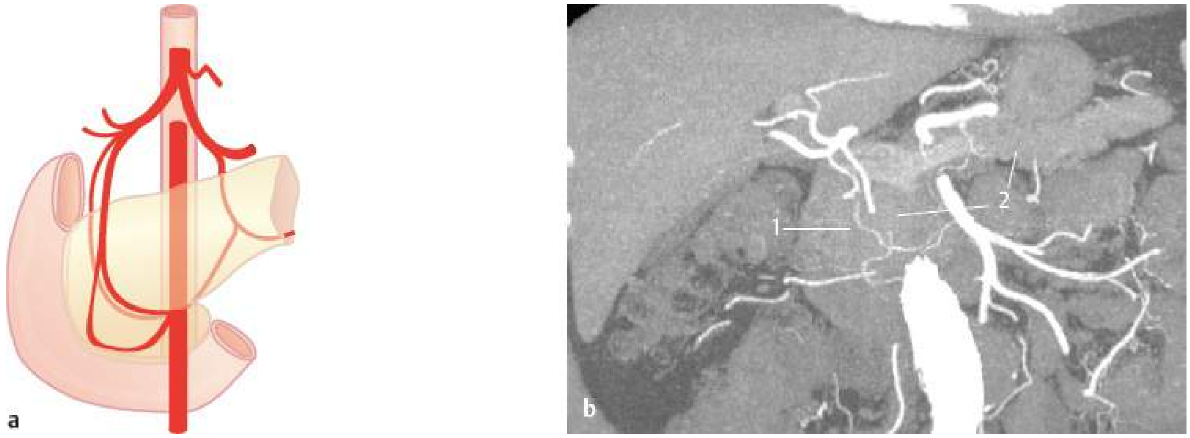

Fig. 18.9 One arcade (90%). Schematic (**a**) and coronal MIP CT (**b**). **1** Posterior arcade; **2** pancreas.

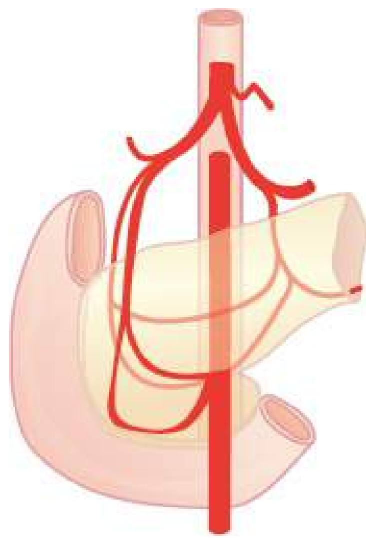

Fig. 18.10 Two arcades (10%). Schematic.

18.5 Superior Origin of the Posterior Arcade

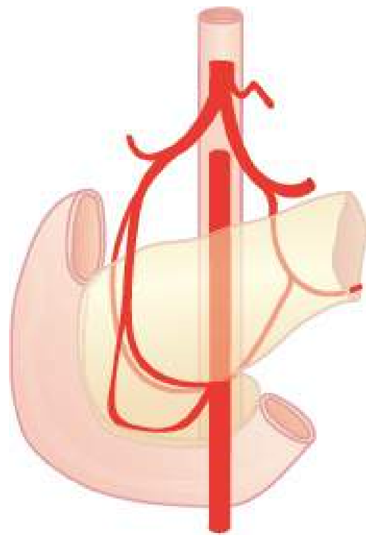

Fig. 18.11 From the gastroduodenal artery (93%). Schematic.

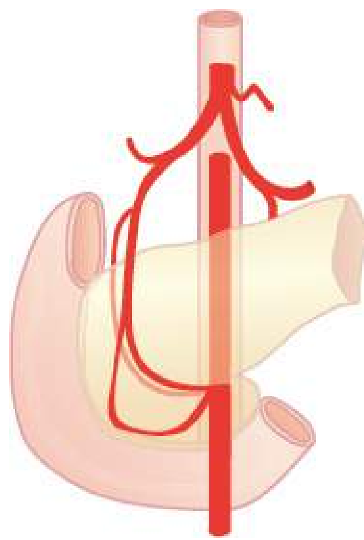

Fig. 18.12 From the common hepatic artery (3%). Schematic.

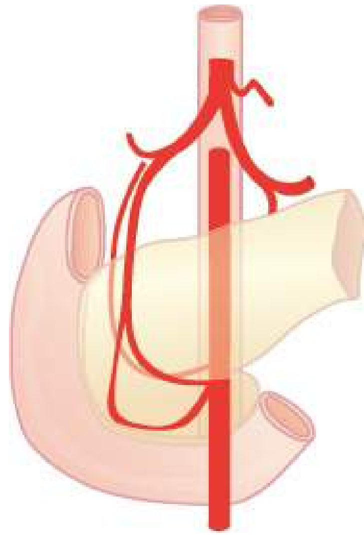

Fig. 18.13 From the proper hepatic artery (2%). Schematic.

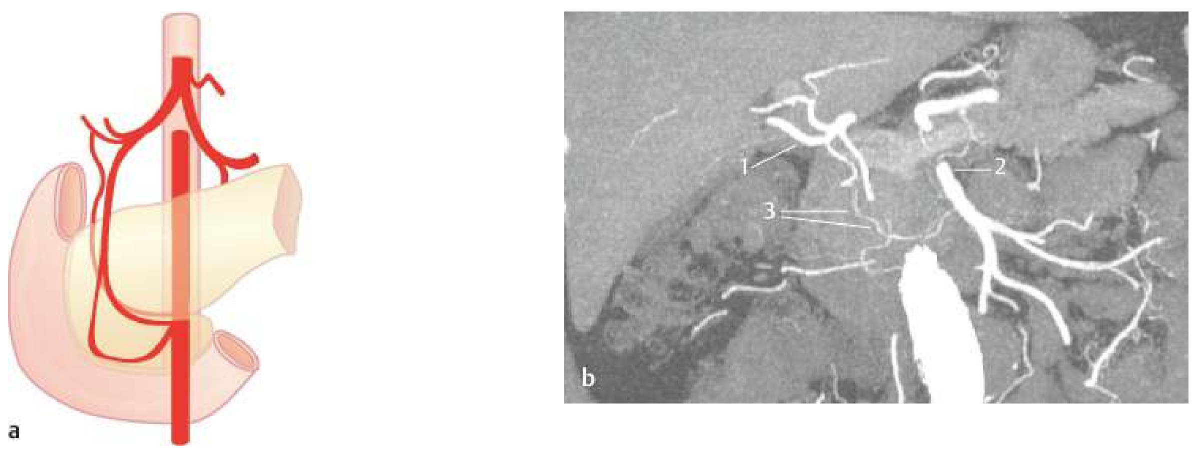

Fig. 18.14 From the right hepatic artery (2%). Schematic (**a**) and coronal MIP CT (**b**). **1** Right hepatic artery; **2** superior mesenteric artery; **3** posterior arcade.

18.6 Origin of the Posterior Pancreatic Artery

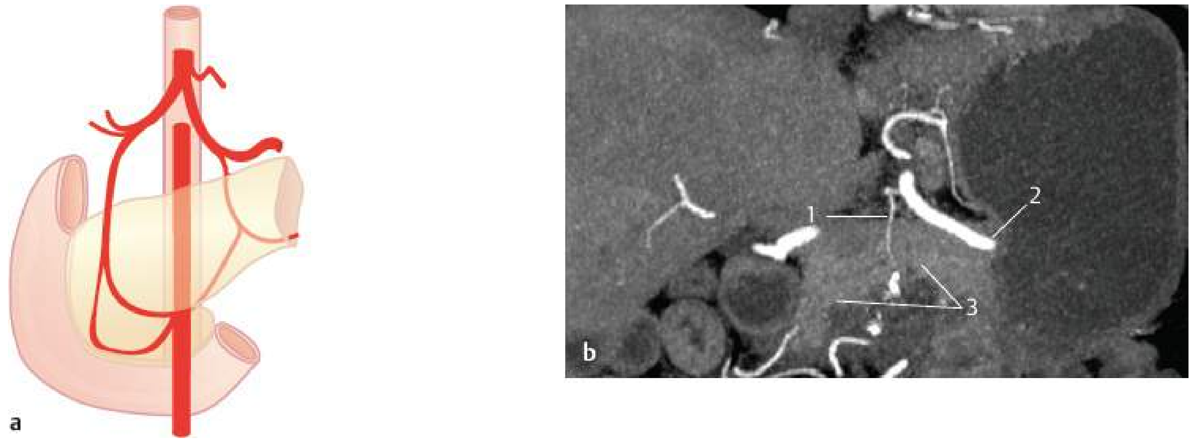

Fig. 18.15 From the splenic artery (40%). Schematic (**a**) and coronal MIP CT (**b**). **1** Posterior pancreatic artery; **2** splenic artery; **3** pancreas.

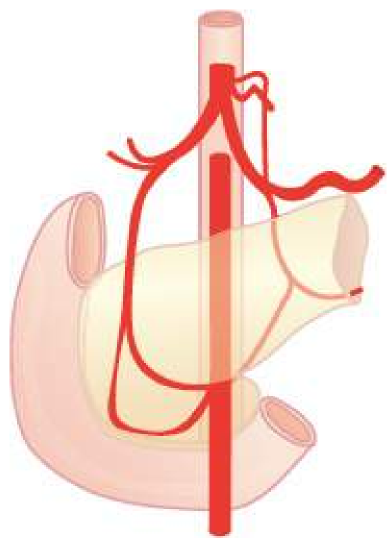

Fig. 18.16 From the celiac trunk (28%). Schematic.

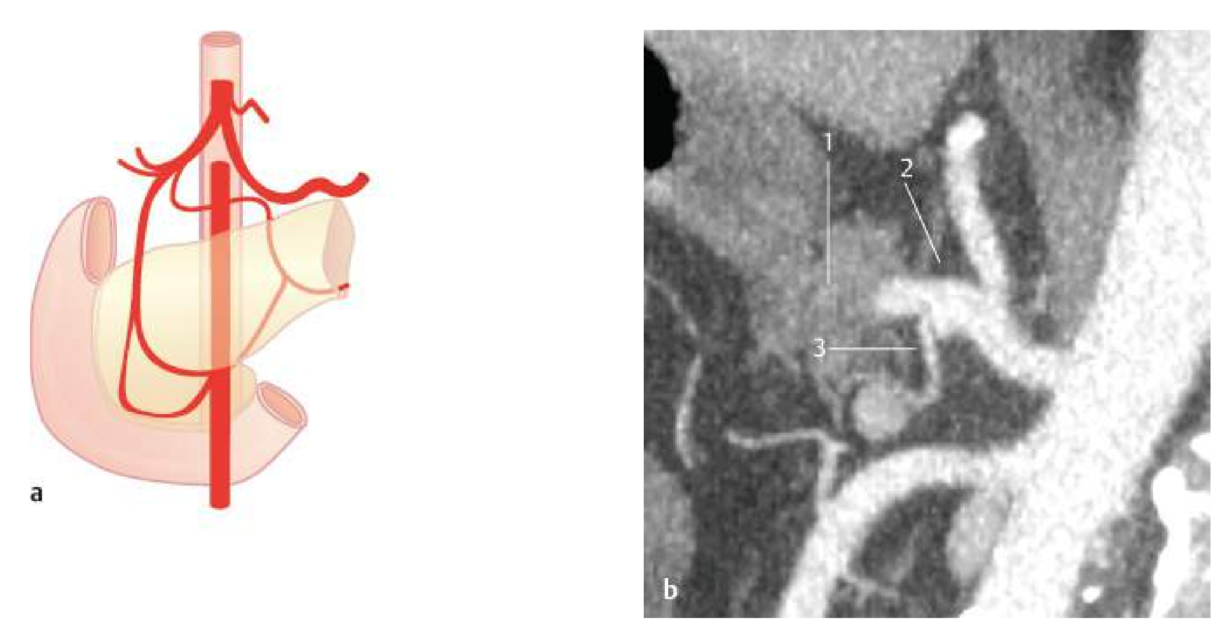

Fig. 18.17 From the common hepatic artery (17%). Schematic (**a**) and sagittal MIP CT (**b**). **1** Pancreas; **2** common hepatic artery; **3** posterior pancreatic artery.

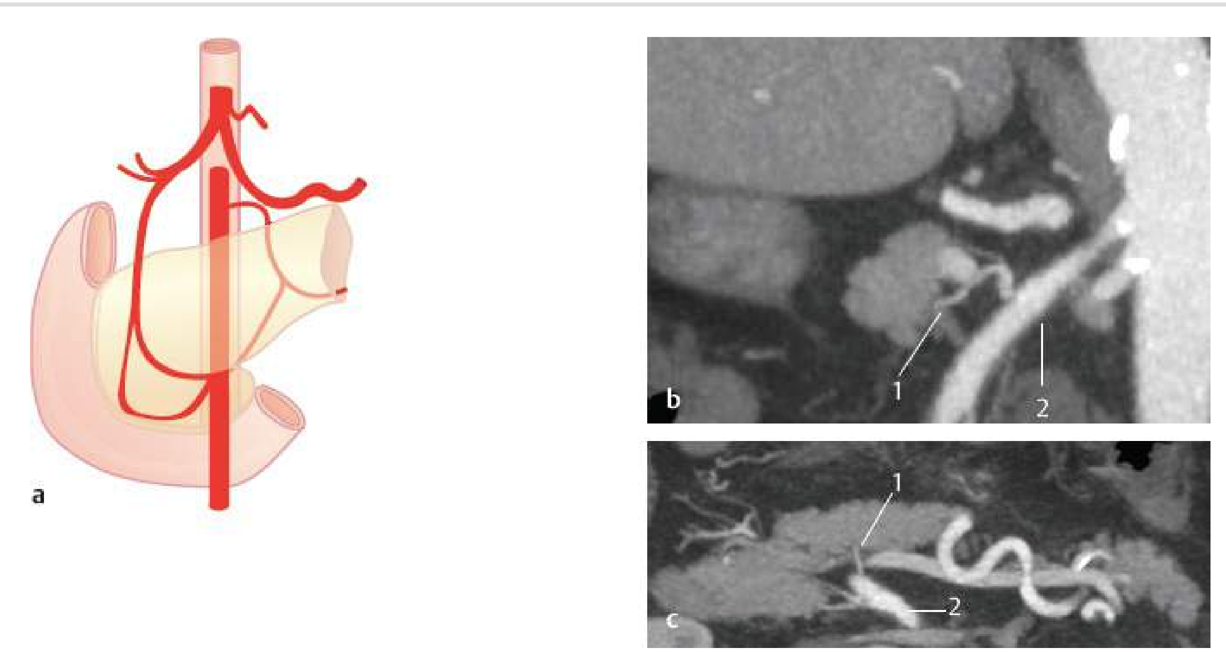

Fig. 18.18 From the superior mesenteric artery (15%). Schematic (**a**) and MIP CT, sagittal (**b**) and axial oblique (**c**) view. **1** Posterior pancreatic artery; **2** superior mesenteric artery.

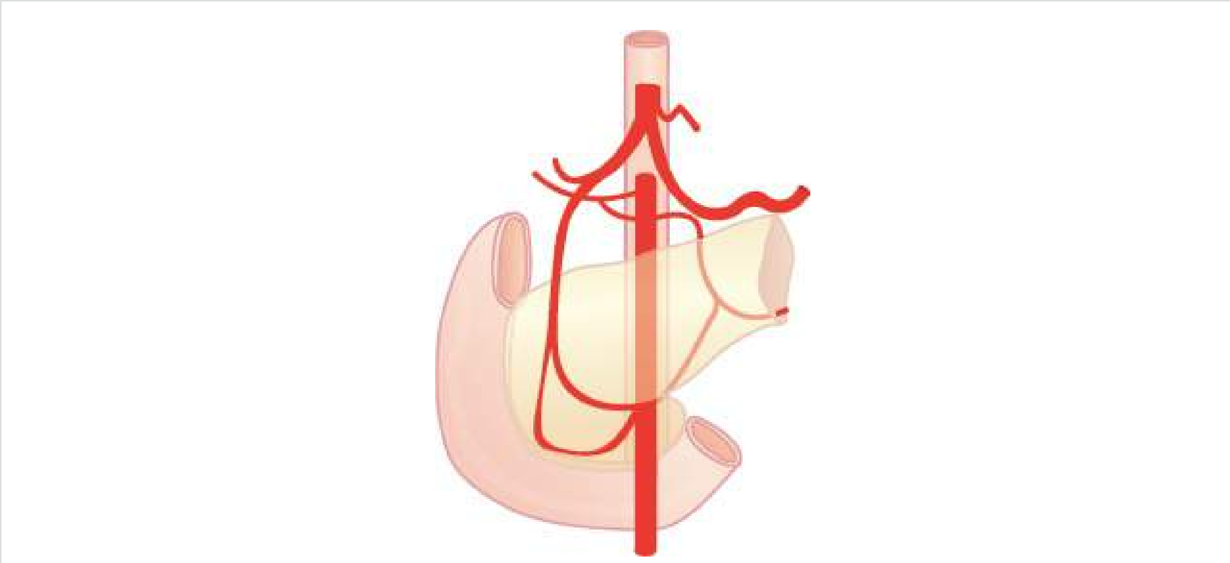

Fig. 18.19 From an aberrant hepatic artery from the superior mesenteric artery (<1%). Schematic.

18.7 Origin of the Transverse Pancreatic Artery

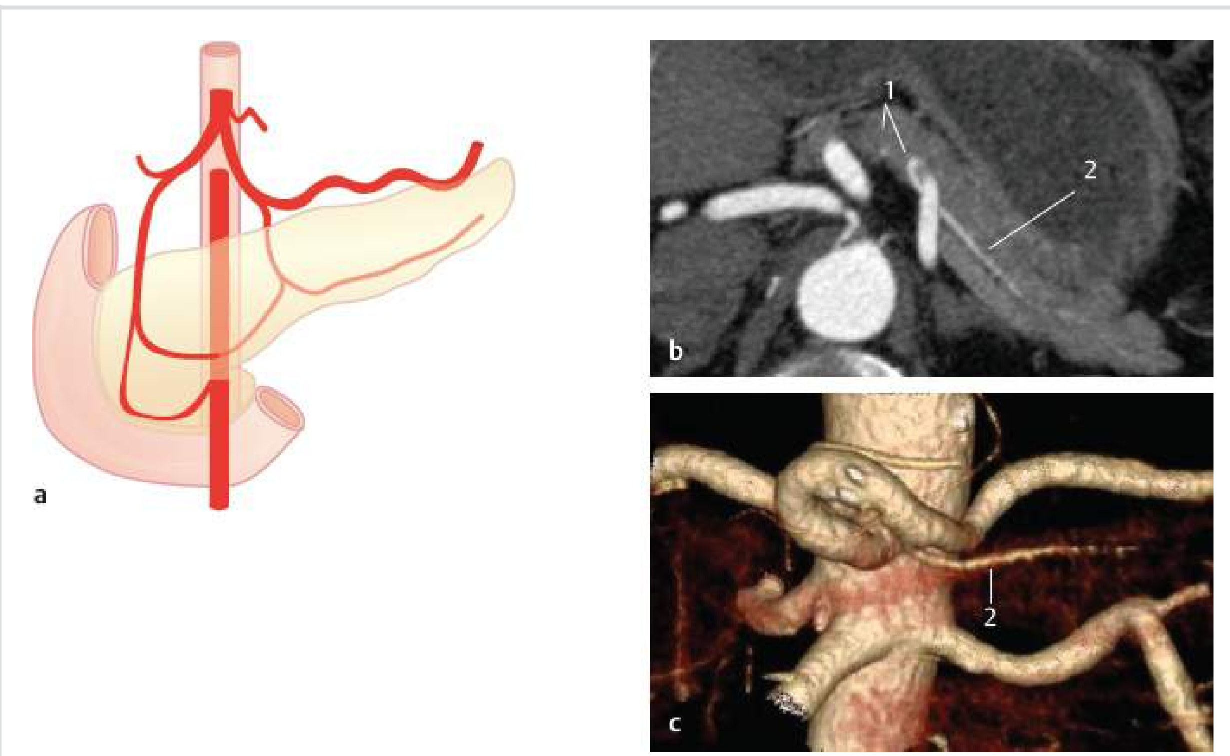

Fig. 18.20 From the posterior pancreatic artery (75%). Schematic

(**a**), axial MIP CT (**b**), and coronal VR CT (**c**). **1** Posterior pancreatic artery; **2** transverse pancreatic artery.

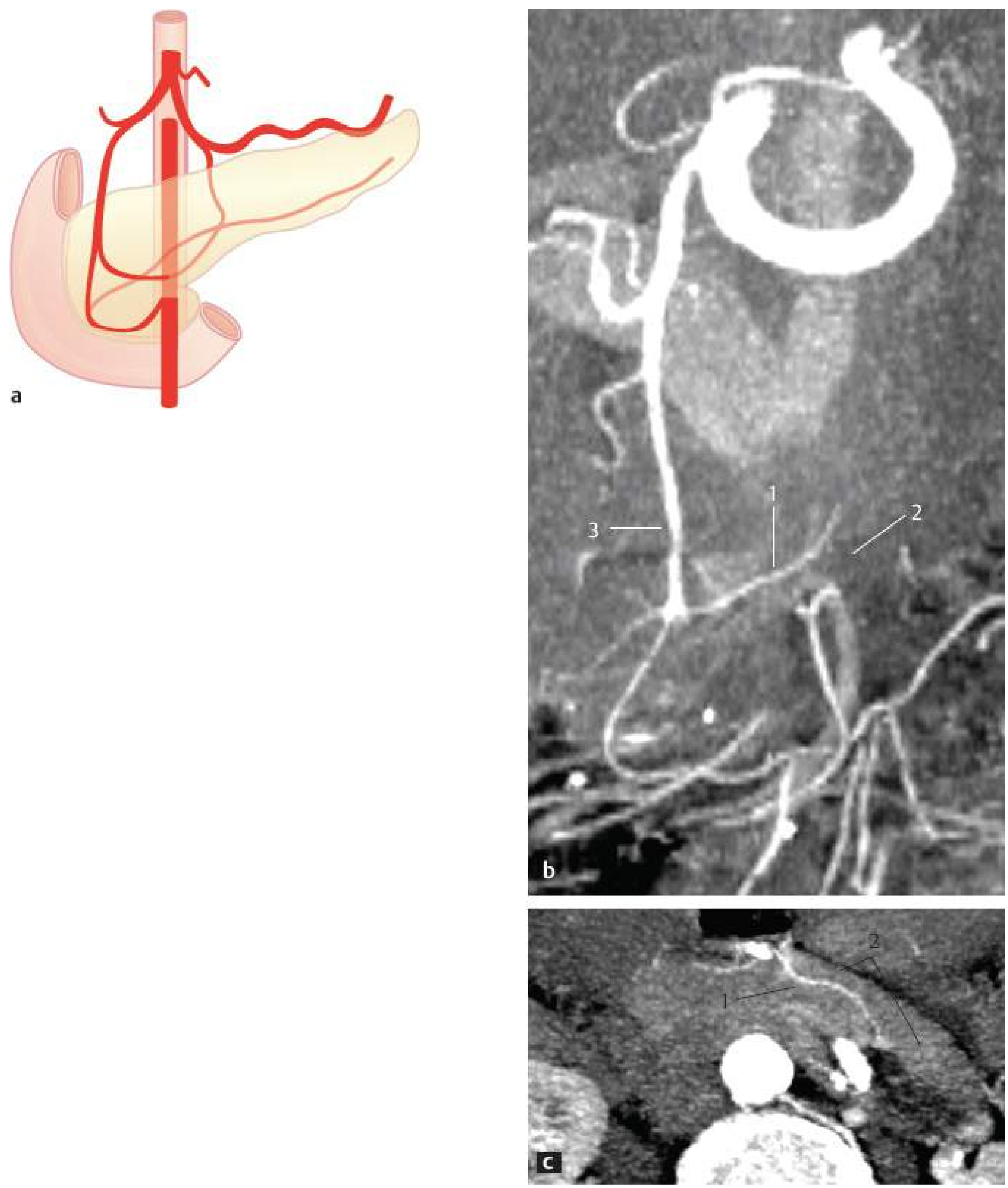

Fig. 18.21 From the anterior arcade (10%). Schematic (**a**) and MIP CT, coronal (**b**) and axial (**c**) views. **1** Transverse pancreatic artery; **2**

pancreas; **3** anterior arcade.

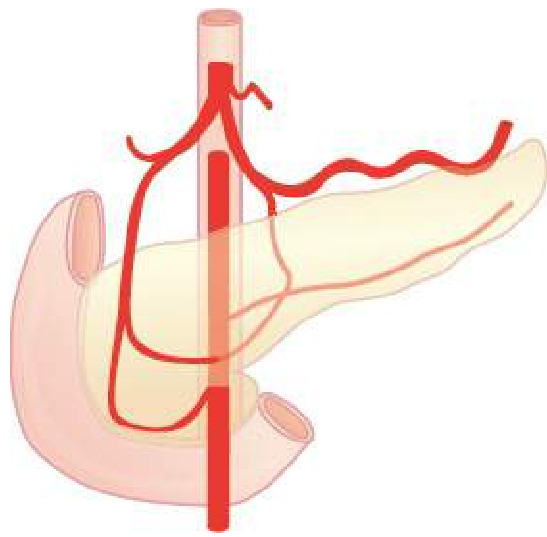

Fig. 18.22 From the superior mesenteric artery (10%). Schematic.

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19 Superior Mesenteric Artery and Celiac Trunk

K.I. Ringe

The basis for these figures are the anomalies of the celiac trunk and the hepatic arteries (for references, see Chapters 13 and 14). The variability of the gastroduodenal artery has also been considered.[1–10] The combination of different accessory arteries has not been included. The figures in this chapters show that there is no clear-cut watershed between organs supplied by the celiac trunk and those supplied by the artery of the embryological midgut, the superior mesenteric artery.

19.1 Blood Supply of the Superior Mesenteric Artery to Abdominal Organs

In the drawings in this chapter, the following designations are used:

– Blank pattern = areas primarily supplied by branches of the celiac trunk.
– Dotted pattern = areas primarily supplied by the superior mesenteric artery, partly by branches of the celiac trunk.
– Striped pattern = areas primarily supplied by the superior mesenteric artery.

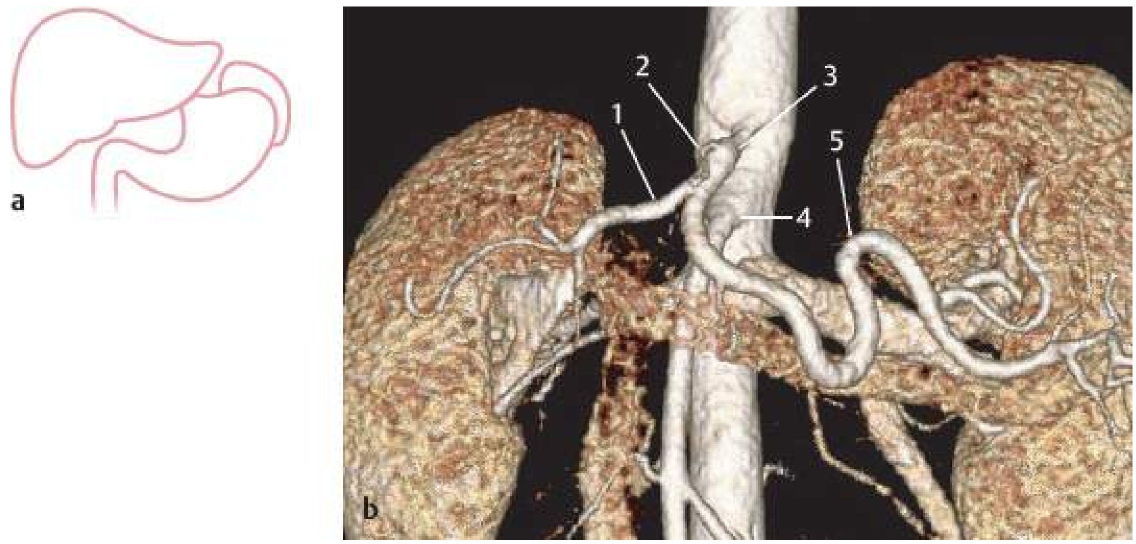

Fig. 19.1 “Normal” type as shown in textbooks (70%). Schematic (**a**) and coronal oblique 3D VR CT (**b**) with typical branching of the celiac trunk and superior mesenteric artery. **1** Common hepatic artery; **2** left gastric artery; **3** celiac trunk; **4** superior mesenteric artery; **5** splenic artery.

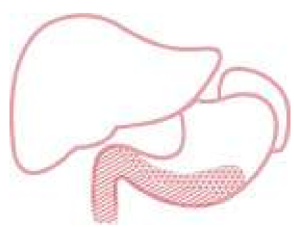

Fig. 19.2 Gastroduodenal artery from the superior mesenteric artery (5%). Schematic.

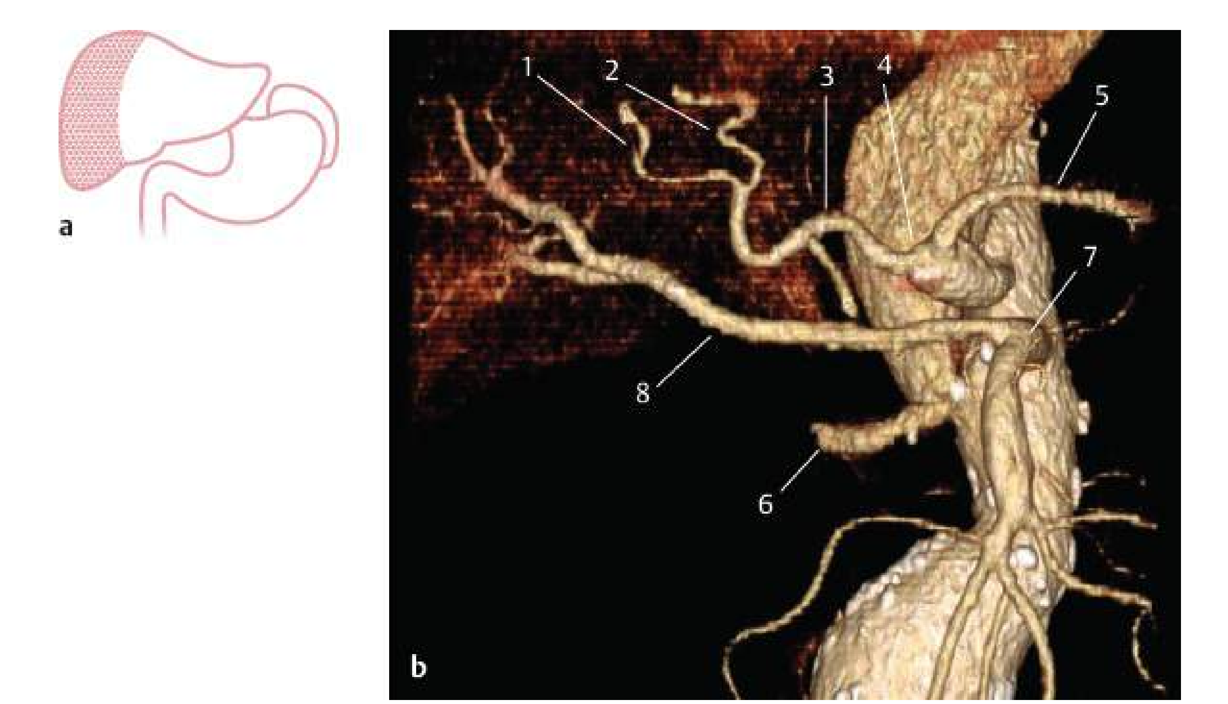

Fig. 19.3 Accessory right hepatic artery from the superior mesenteric artery (6%). Schematic (**a**) and coronal oblique 3D VR CT (**b**) in a patient with aortic dissection. **1** Right hepatic artery; **2** left hepatic artery; **3** common hepatic artery; **4** celiac trunk; **5** splenic artery; **6** right renal artery; **7** superior mesenteric artery; **8** accessory right hepatic artery.

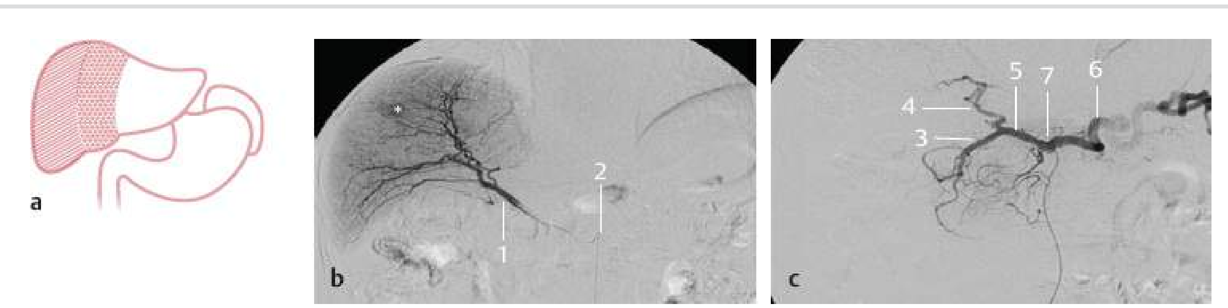

Fig. 19.4 Right hepatic artery from the superior mesenteric artery (10%). Schematic (**a**) and subtracted DSA, with the diagnostic catheter placed in the superior mesenteric artery (**b**) and the celiac trunk (**c**). Patient with hepatocellular carcinoma (*). **1** Right hepatic artery; **2** superior mesenteric artery; **3** gastroduodenal artery; **4** left hepatic artery; **5** common hepatic artery; **6** splenic artery; **7** celiac trunk.

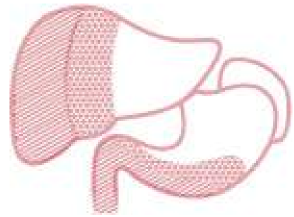

Fig. 19.5 Right hepatic and gastroduodenal arteries from the superior mesenteric artery (1%). Schematic.

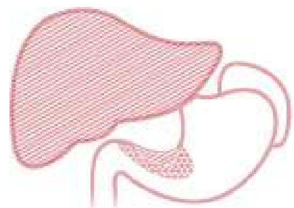

Fig. 19.6 Proper hepatic artery from the superior mesenteric artery (3%). Schematic.

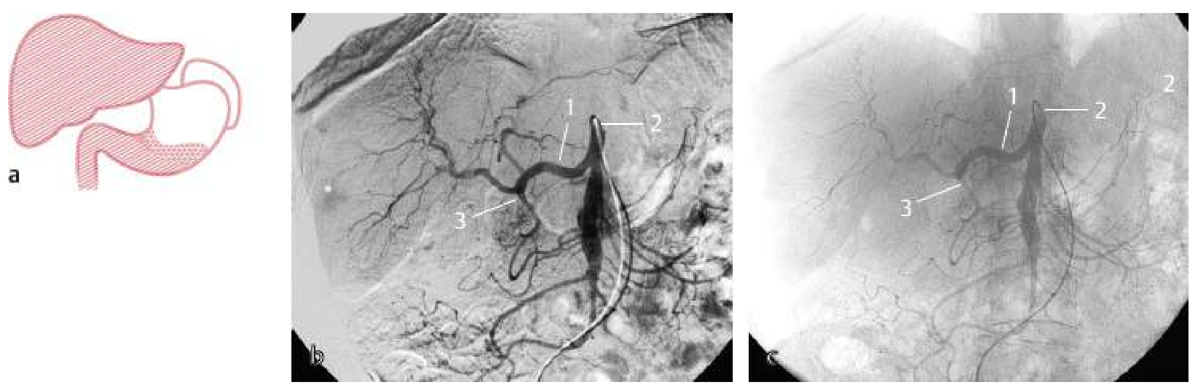

Fig. 19.7 Common hepatic artery (hepatomesenteric trunk) from the superior mesenteric artery (5%). Schematic (**a**) as well as subtracted (**b**) and nonsubtracted (**c**) DSA. The patient has hepatocellular carcinoma with hypervascular lesions (*) in the right lobe of the liver. **1** Common hepatic artery; **2** superior mesenteric artery; **3** gastroduodenal artery.

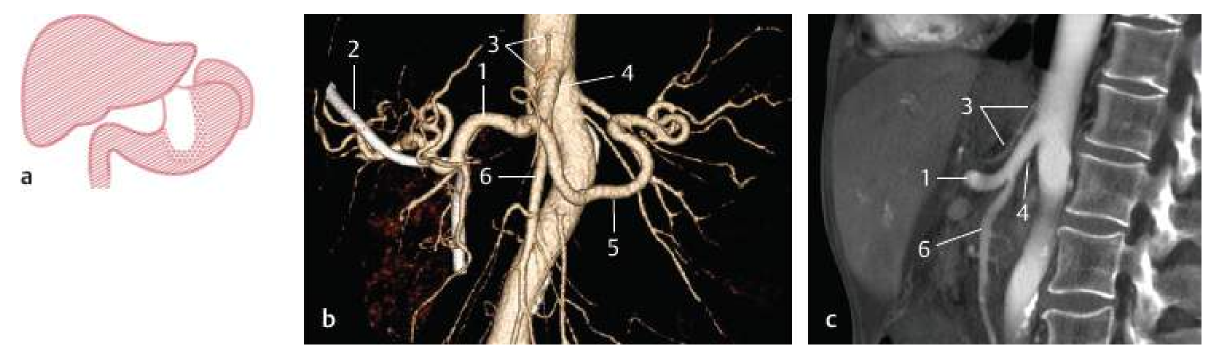

Fig. 19.8 Common hepatic and splenic arteries form a common trunk with the superior mesenteric artery (hepatosplenomesenteric trunk) (1%). Schematic (**a**), coronal oblique 3D VR CT image (**b**), and sagittal AvIP reformation (**c**). The left gastric artery is a separate branch from the abdominal aorta. In addition, a stent can be appreciated in the common bile duct. **1** Common hepatic artery; **2** stent; **3** left gastric artery; **4** hepatosplenomesenteric trunk; **5** splenic artery; **6** superior mesenteric artery.

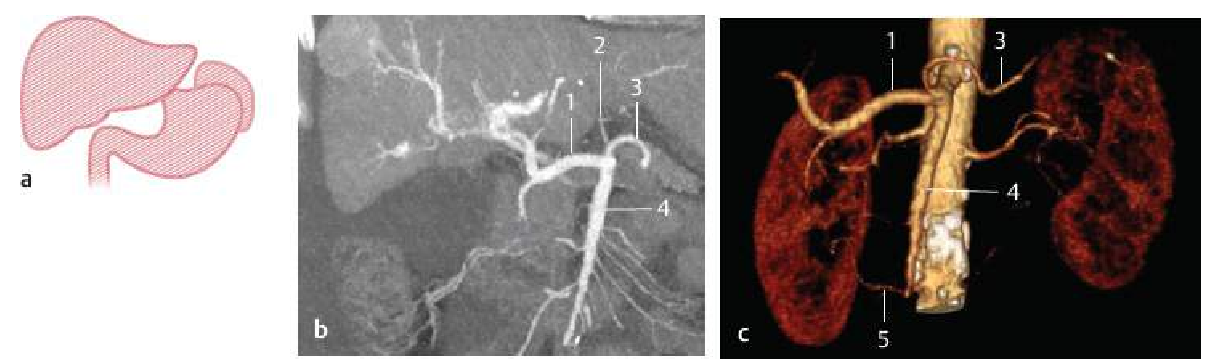

Fig. 19.9 Celiac trunk and superior mesenteric artery have a common origin (gastrohepatosplenomesenteric trunk) (2%). Schematic (**a**) as well as coronal MIP CT (**b**) and coronal VR CT (**c**) of a patient with liver cirrhosis and an arterioportal shunt (*) in the liver hilum. In addition, a right lower polar renal artery can be appreciated. **1** Common hepatic artery; **2** left gastric artery; **3** splenic artery; **4** superior mesenteric artery; **5** lower pole artery.

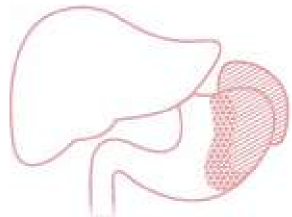

Fig. 19.10 Splenic artery originates with the superior mesenteric artery (splenomesenteric trunk) (1%). Schematic.

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20 Superior Mesenteric Artery and Colic Arteries

K.I. Ringe

The gastroduodenal arteries (see Chapter 14 and 17), the jejunal, and ileal arteries are not depicted, but the arteries supplying the colon, cecum, and appendix are outlined in detail.[1–16] The ileocolic artery is the most variable of the colic branches from the superior mesenteric artery. Accessory middle colic arteries are of clinical importance, since in such cases the arterial blood supply of the colon by the superior mesenteric artery is extended to the left colic flexure or even as far as the descending colon. Accessory middle colic arteries have been described as branches of the gastroduodenal or left gastroepiploic arteries. if accessory branches from the inferior mesenteric artery are present, arteries supply the transverse colon up to the right colic flexure. Normally the anastomosis along the colon formed by different arches (marginal artery) is large enough to ensure a sufficient collateral circulation (anastomosis of Riolan). This anastomosis between the superior and inferior mesenteric arteries is absent in approximately 2% of all cases, and in a further 3% it is very small. The arch between the right colic and the ileocolic arteries seems to be absent in approximately 6% of all cases.[1,2,9,13,17–30]

20.1 Three Colic Arteries Branch from the Superior Mesenteric Artery (67%)

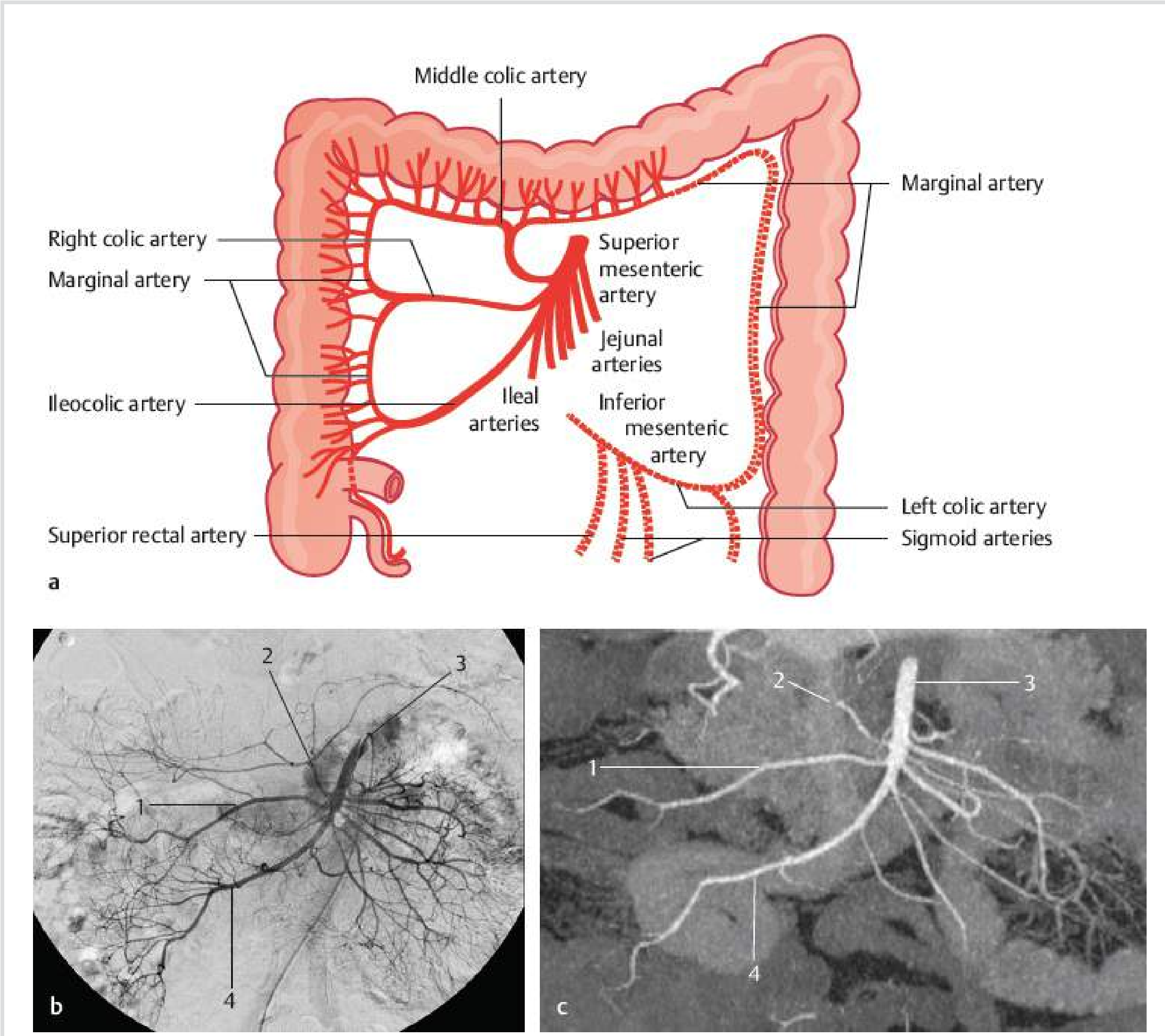


Fig. 20.1 The ileocolic, right, and middle colic arteries are independent branches of the superior mesentery artery (24%). Schematic (**a**), DSA of the superior mesenteric artery (**b**), and coronal MIP CT of the superior mesenteric artery (**c**). **1** Right colic artery; **2** middle colic artery; **3** superior mesenteric artery; **4** ileocolic artery.

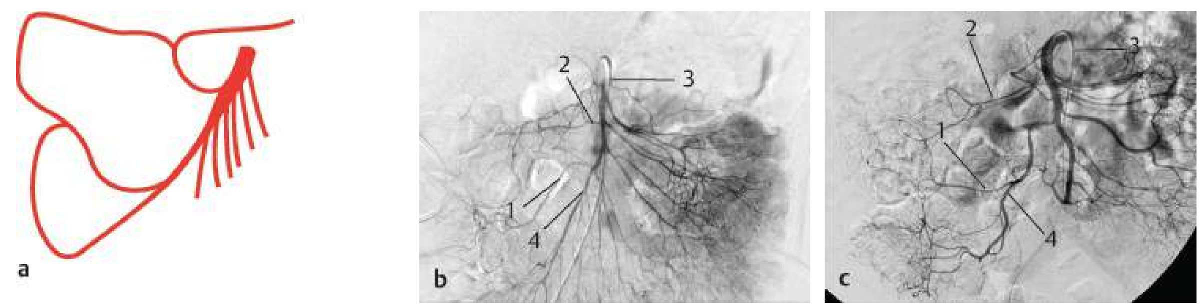


Fig. 20.2 The ileocolic and right colic arteries form a trunk (20%). Schematic (**a**) and DSA of the superior mesenteric artery of two patients (**b,c**). **1** Right colic artery; **2** middle colic artery; **3** superior mesenteric artery; **4** ileocolic artery.

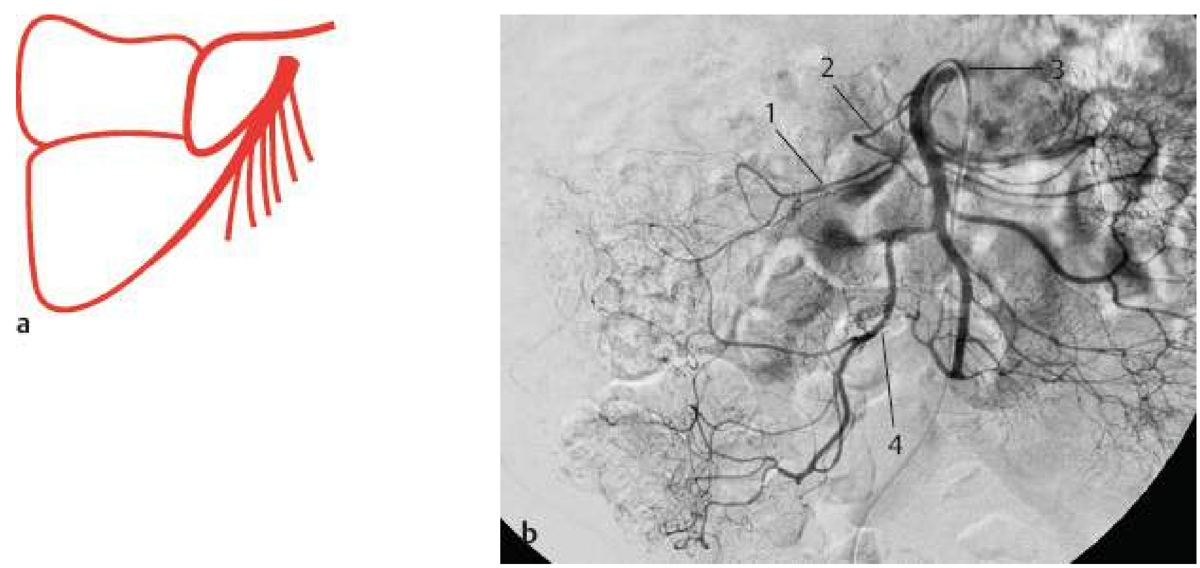


Fig. 20.3 The right and middle colic arteries from a common trunk (22%). Schematic (**a**) and DSA of the superior mesenteric artery (**b**). **1** Right colic artery; **2** middle colic artery; **3** superior mesenteric artery; **4** ileocolic artery.

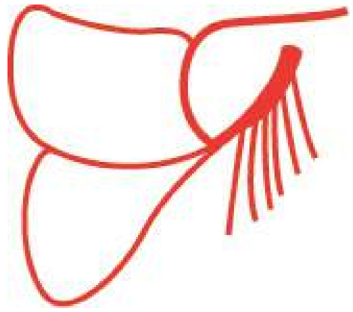


Fig. 20.4 The ileocolic, right, and middle colic arteries form a common trunk (1%). Schematic.

20.2 Two Colic Arteries Branch from the Superior Mesenteric Artery (15%)

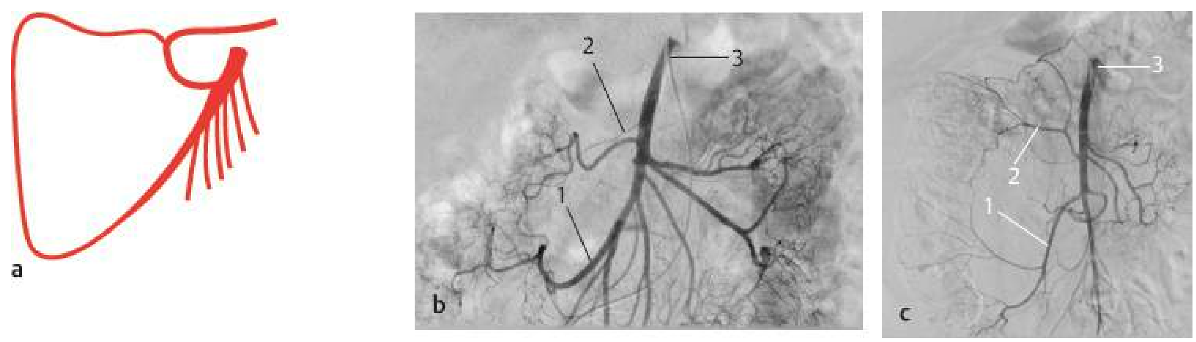


Fig. 20.5 The right colic artery is absent (10%). The ileocolic and middle colic arteries in such cases normally branch separately from the superior mesenteric artery. Schematic (**a**) and DSA of the superior mesenteric artery of two patients (**b,c**). **1** Ileocolic artery; **2** middle colic artery; **3** superior mesenteric artery.

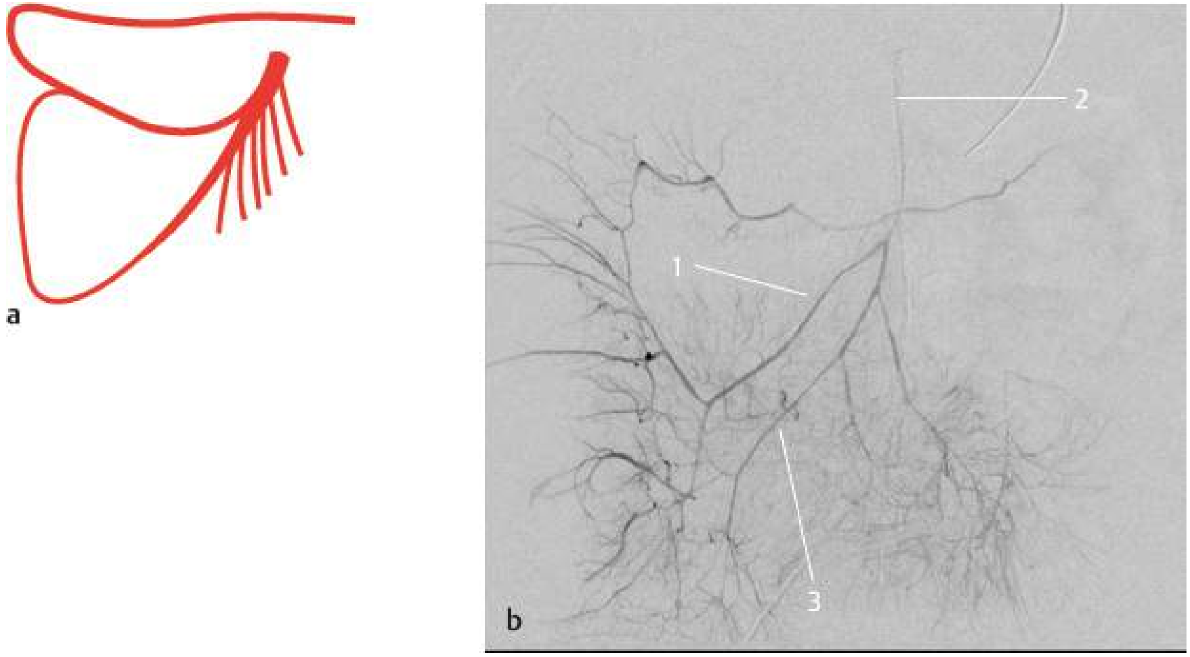


Fig. 20.6 The middle colic artery is absent (5%). The ileocolic and right colic arteries branch separately in three-fourth of all cases; otherwise they form a common trunk. Schematic (**a**) and DSA of the superior mesenteric artery (**b**). **1** Right colic artery; **2** superior mesenteric artery; **3** ileocolic artery.

20.3 Accessory Colic Arteries (18%)

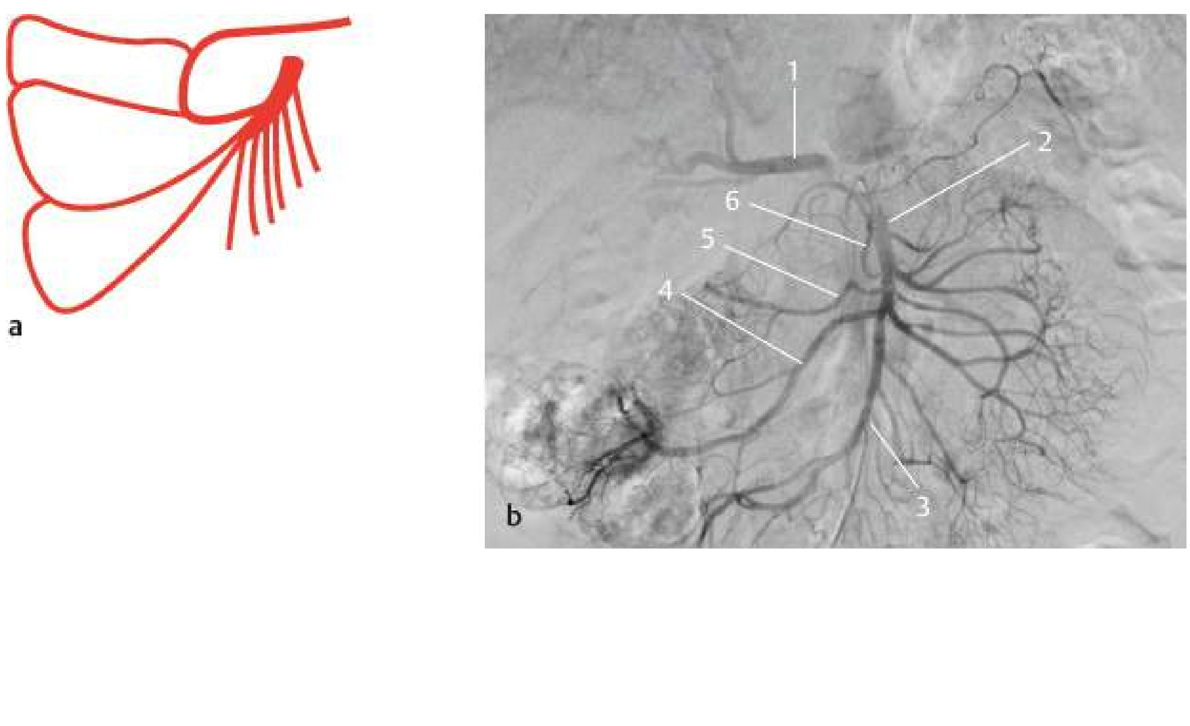


Fig. 20.7 Two right colic arteries normally from common trunks with the middle colic and ileocolic artery (6%). Schematic (**a**) and DSA of the superior mesenteric artery (**b**). In addition, the patient has a replaced right hepatic artery from the superior mesenteric artery. **1** Right hepatic artery; **2** superior mesenteric artery; **3** ileocolic artery; **4** right colic artery 1; **5** right colic artery 2; **6** middle colic artery.

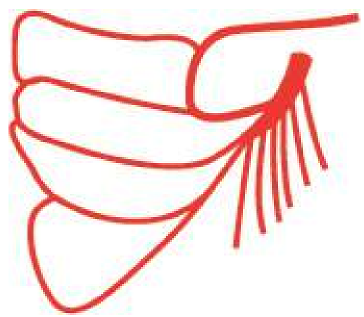


Fig. 20.8 Three right colic arteries (1%). Schematic.

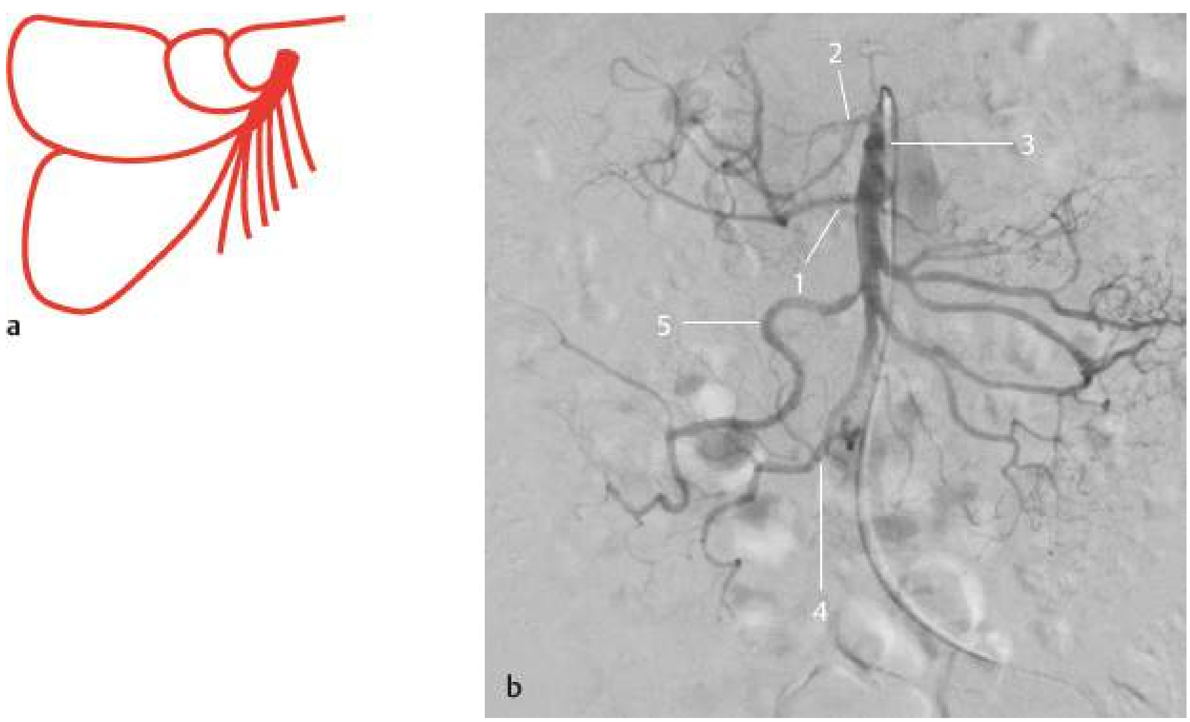
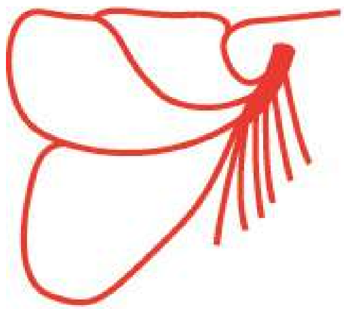
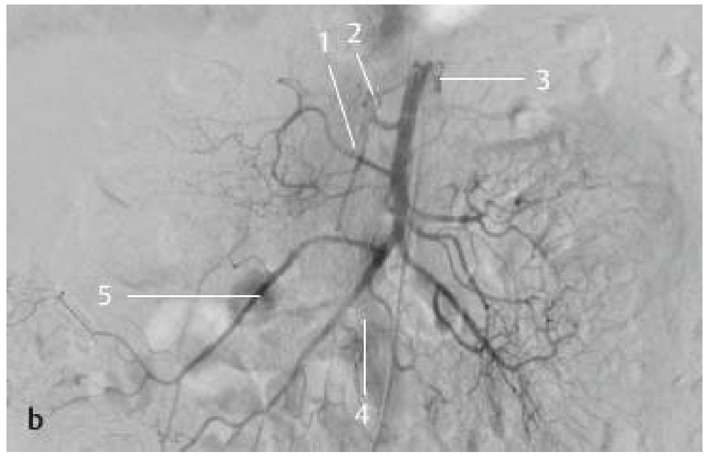


Fig. 20.9 Two middle colic arteries; all four colic arteries originate separately (1%). Schematic (**a**) and DSA of the superior mesenteric

artery (**b**). **1** Middle colic artery 1; **2** middle colic artery 2; **3** superior mesenteric artery; **4** ileocolic artery; **5** right colic artery.



a



b

Fig. 20.10 Two middle colic arteries with a common trunk of the ileocolic and right colic arteries (4%). Schematic (**a**) and DSA of the superior mesenteric artery (**b**). **1** Middle colic artery 1; **2** middle colic artery 2; **3** superior mesenteric artery; **4** ileocolic artery; **5** right colic artery.

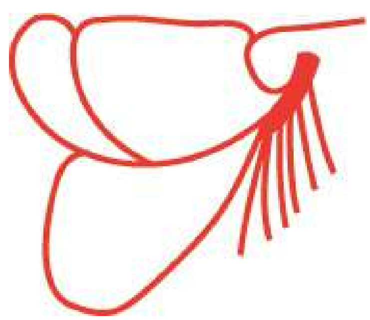


Fig. 20.11 Two middle colic arteries with a common trunk of one middle colic artery and the right colic artery (4%). Schematic.

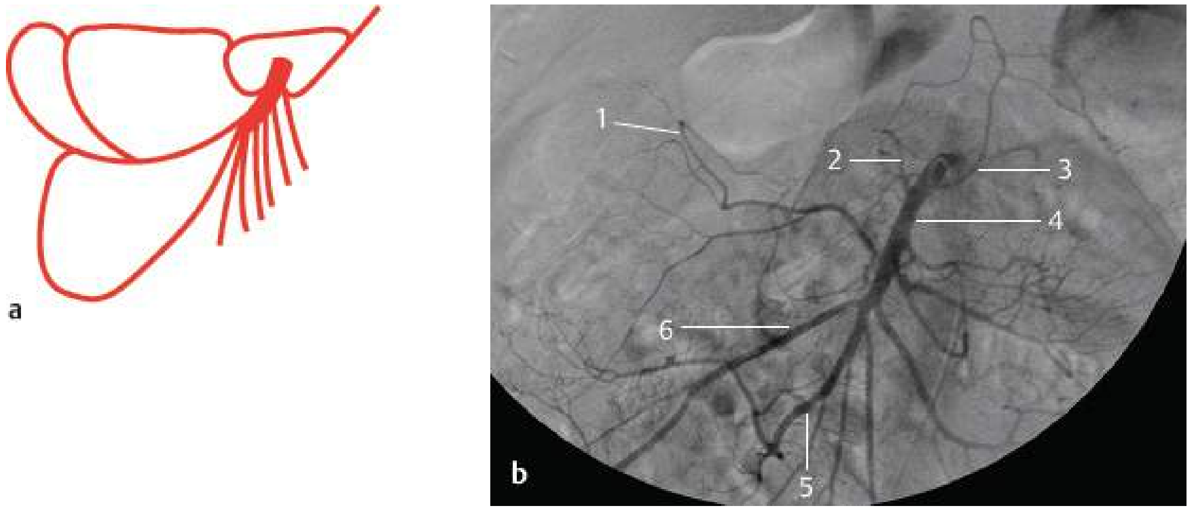


Fig. 20.12 Three middle colic arteries (2%). Schematic (**a**) and DSA of the superior mesenteric artery (**b**). **1** Middle colic artery 1; **2** middle colic artery 2; **3** middle colic artery 3; **4** superior mesenteric artery; **5** ileocolic artery; **6** right colic artery.

20.4 Left Colic Artery Is a Branch of the Superior Mesenteric Artery (<1%)

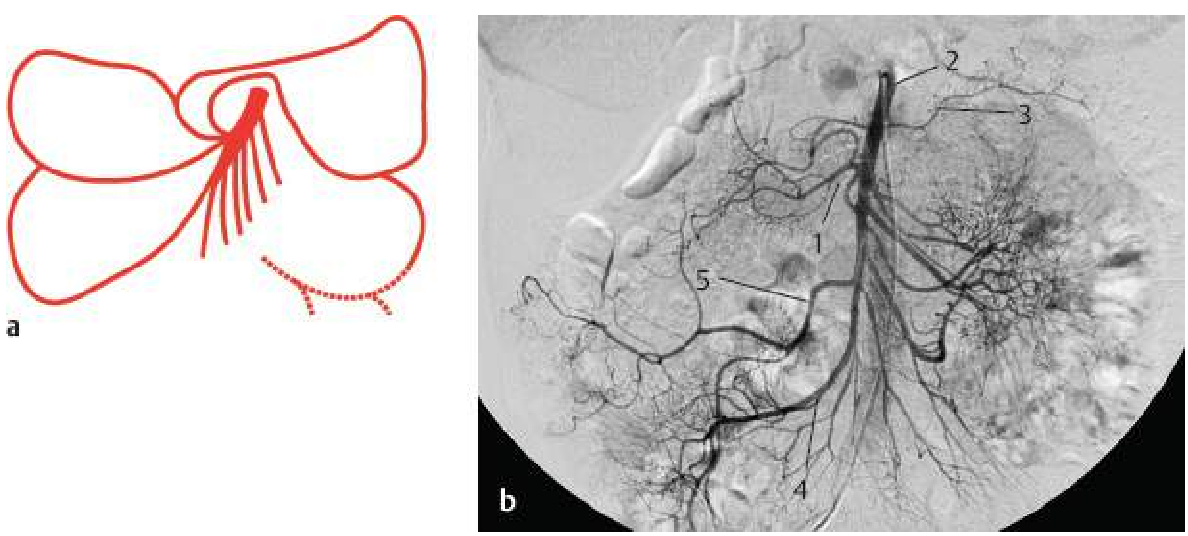


Fig. 20.13 Left accessory colic artery from the superior mesenteric or middle colic arteries (<1%). Schematic (**a**) and DSA

of the superior mesenteric artery (**b**). **1** Middle colic artery; **2** superior mesenteric artery; **3** accessory left colic artery; **4** ileocolic artery; **5** right colic artery.

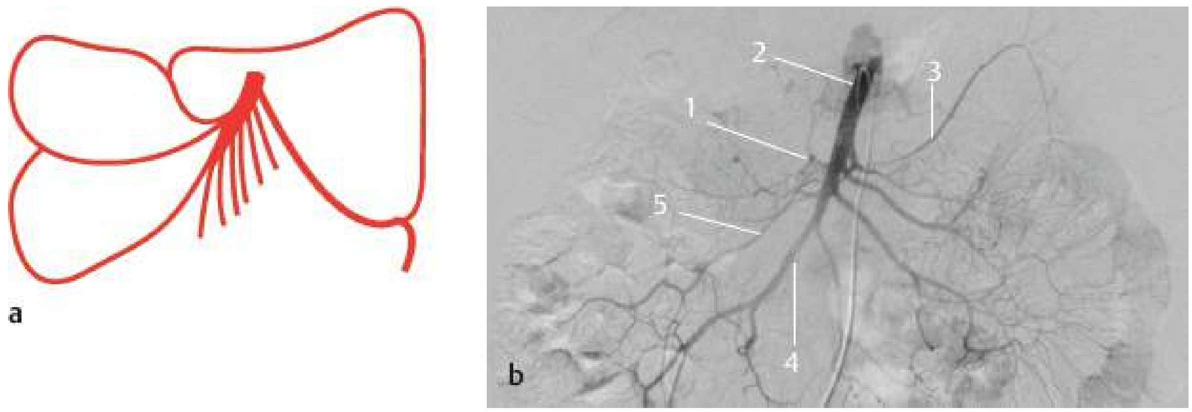


Fig. 20.14 Main stem of the left colic artery originates from the superior mesenteric artery (sometimes from a common trunk with the middle colic artery) (<1%). Schematic (**a**) and DSA (**b**) with the main stem of the left colic artery originating from the superior mesenteric artery. **1** Middle colic artery; **2** superior mesenteric artery; **3** left colic artery; **4** ileocolic artery; **5** right colic artery.

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21 Appendicular Artery

K.I. Ringe, S. Meyer

The drawings showing the appendicular artery are very schematic because variations of the ascending, anterior, and posterior cecal arteries have not been included. The appendicular artery can run anteriorly to the ileum if this artery branches very distally from the cecal artery. Normally even an appendicular artery as a branch of the anterior cecal artery runs posteriorly to the ileum. Duplications of the appendicular artery have been described if one artery is posterior and the other anterior to the ileum.[1–8]

21.1 Appendicular Artery Runs Posteriorly to the Ileum (>99%)

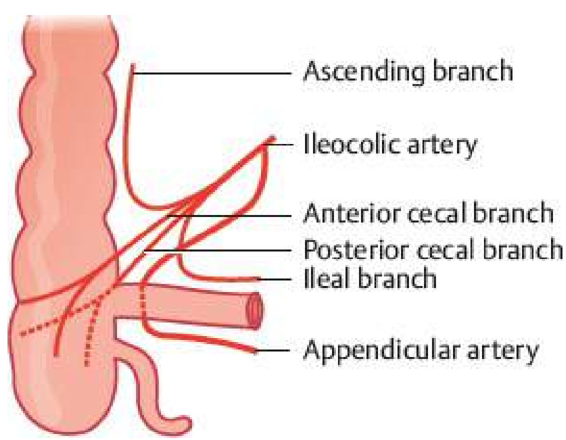

Fig. 21.1 Origin from the ileocolic artery proximal to its division (3%). Schematic.

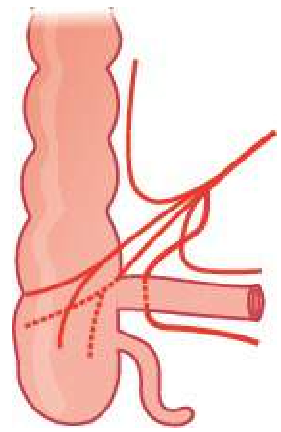

Fig. 21.2 Origin from the division of the ileocolic artery (28%). Schematic.

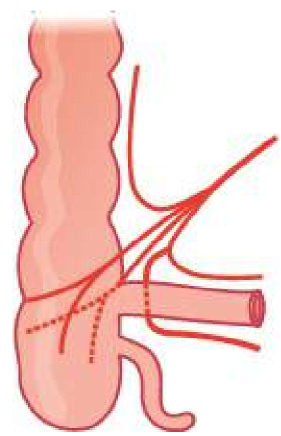

Fig. 21.3 Origin from the last branch to the ileum (35%). Schematic.

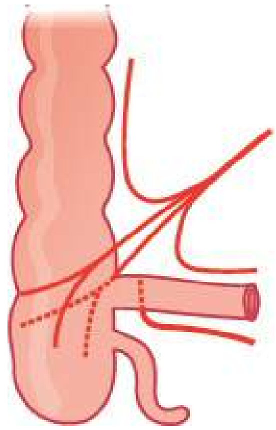

Fig. 21.4 Origin from a posterior cecal artery (12%). Schematic.

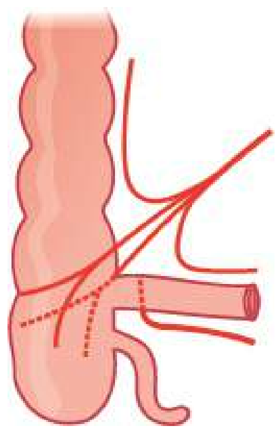

Fig. 21.5 Origin from the anterior cecal artery (20%). Schematic.

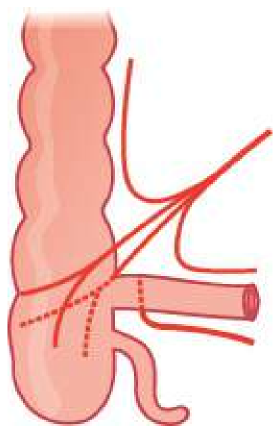

Fig. 21.6 Origin from the ascending cecal branch or a common

trunk of the ileocolic and right colic artery (2%). Schematic.

21.2 Appendicular Artery Runs Anteriorly to the Ileum (<1%)

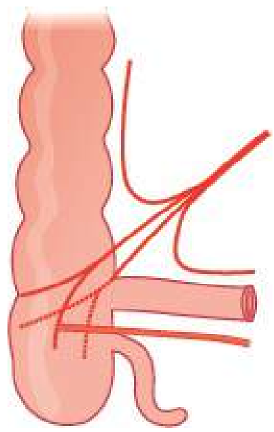

Fig. 21.7 Appendicular artery runs anteriorly to the ileum (<1%). Schematic.

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22 Inferior Mesenteric Artery

K.I. Ringe, S. Meyer

The inferior mesenteric artery is an artery with a generally constant origin. It nearly always originates from the aorta, usually at the height of the third lumbar vertebra, supplying parts of the transverse colon, the descending colon, sigmoid, and parts of the rectum.[1–17] The number of branches to the sigmoid varies considerably from one to six. For the sake of clarity, only two sigmoid arteries are outlined in the respective drawings. The most important end branch of the inferior mesenteric artery is the superior rectal artery, which in 80% of all cases divides into two main branches. These anastomose with the four other rectal arteries, which are branches of the internal iliac artery.[3,18] The superior rectal artery is the main arterial blood supply to the rectum. Therefore, a ligature distal to the last anastomosis with a sigmoid artery (the point of Sudeck) can be dangerous. These rectal anastomoses can be of clinical importance when the external iliac artery is occluded and the collateral blood supply of the leg uses the inferior mesenteric, superior rectal, internal iliac, or femoral arteries. In such cases, a mesenteric steal syndrome can be observed.[15,19]

It is difficult to define an exact border between the areas supplied by the superior and inferior mesenteric arteries because of the arterial arches, the marginal arteries along the colon. In anatomical studies (arterial dissections), the border is normally delimited more orally than in angiographic studies. Angiography shows the functional situation better but gives evidence only for the area supplied by the dye-injected artery and does not exclude an additional supply by another artery. **Fig. 22.1** represents a compromise between anatomical and angiographic data.[11,16,17,19–25]

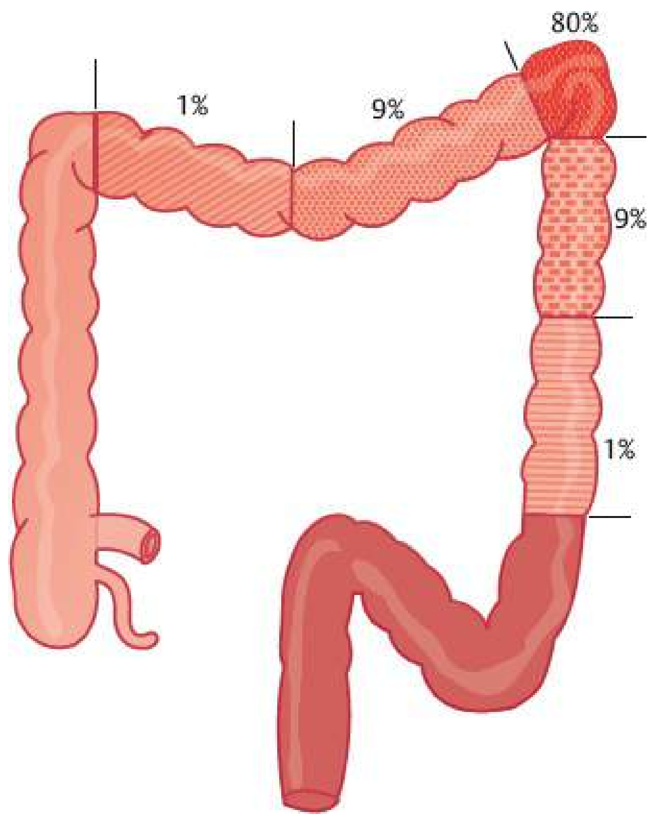

Fig. 22.1 Schematic demonstration of observed localizations of the watershed area between the superior and the inferior mesenteric artery; the percentages indicate the frequency of each localization.

22.1 The Inferior Mesenteric Artery Branches into the Left Colic Artery, Sigmoid Arteries, and the Superior Rectal Artery (89%)

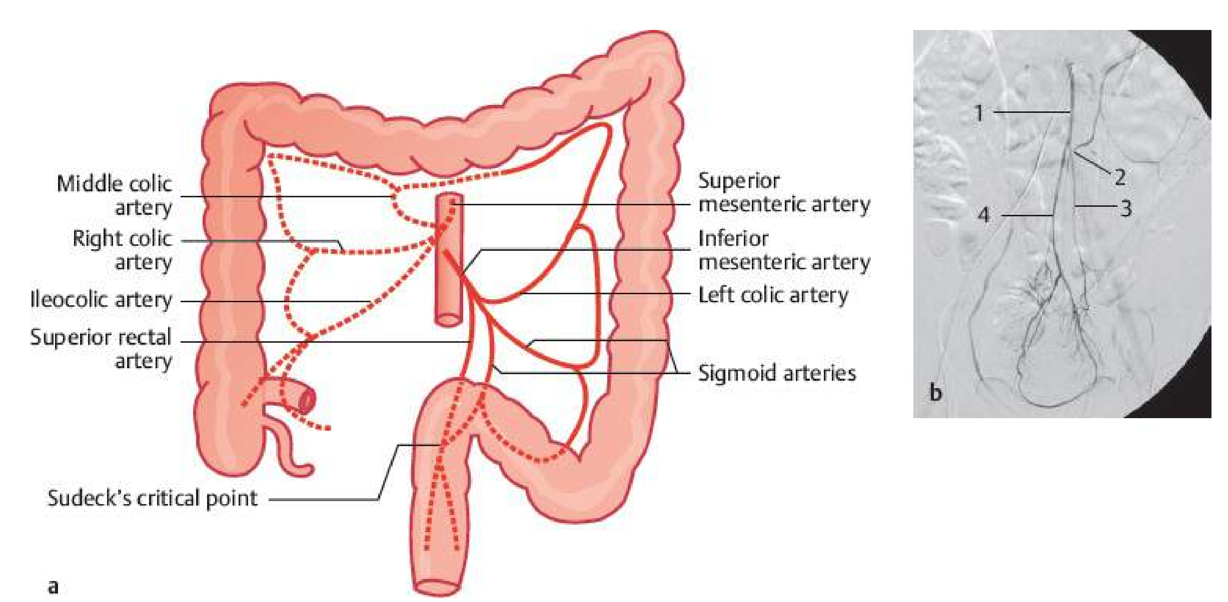

Fig. 22.2 Trifurcation of the main stem of the inferior mesenteric artery (~25%). Schematic (**a**) and DSA (**b**). Besides, urethral contrast excretion can be appreciated (*). **1** Inferior mesenteric artery; **2** left colic artery; **3** sigmoid arteries; **4** superior rectal artery.

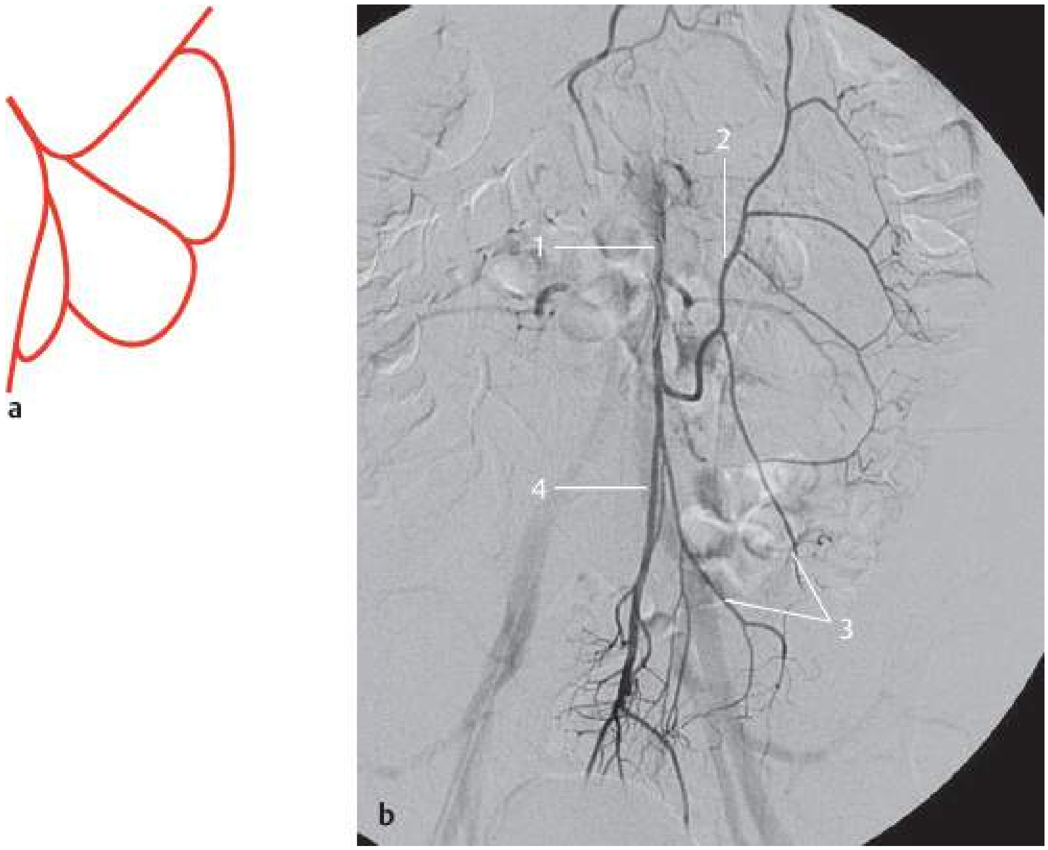

Fig. 22.3 Bifurcation of the main stem of the inferior mesenteric artery; both stems give off branches to the sigmoid (~30%). Schematic (**a**) and DSA (**b**). **1** Inferior mesenteric artery; **2** left colic artery; **3** sigmoid branches; **4** superior rectal artery.

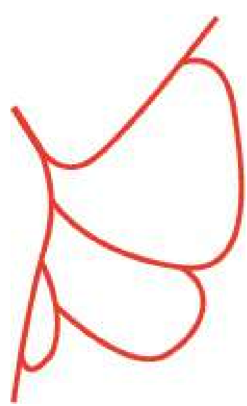

Fig. 22.4 Bifurcation of the main stem of the inferior mesenteric artery; the sigmoid arteries originate only from the superior rectal

artery (~25%). Schematic.

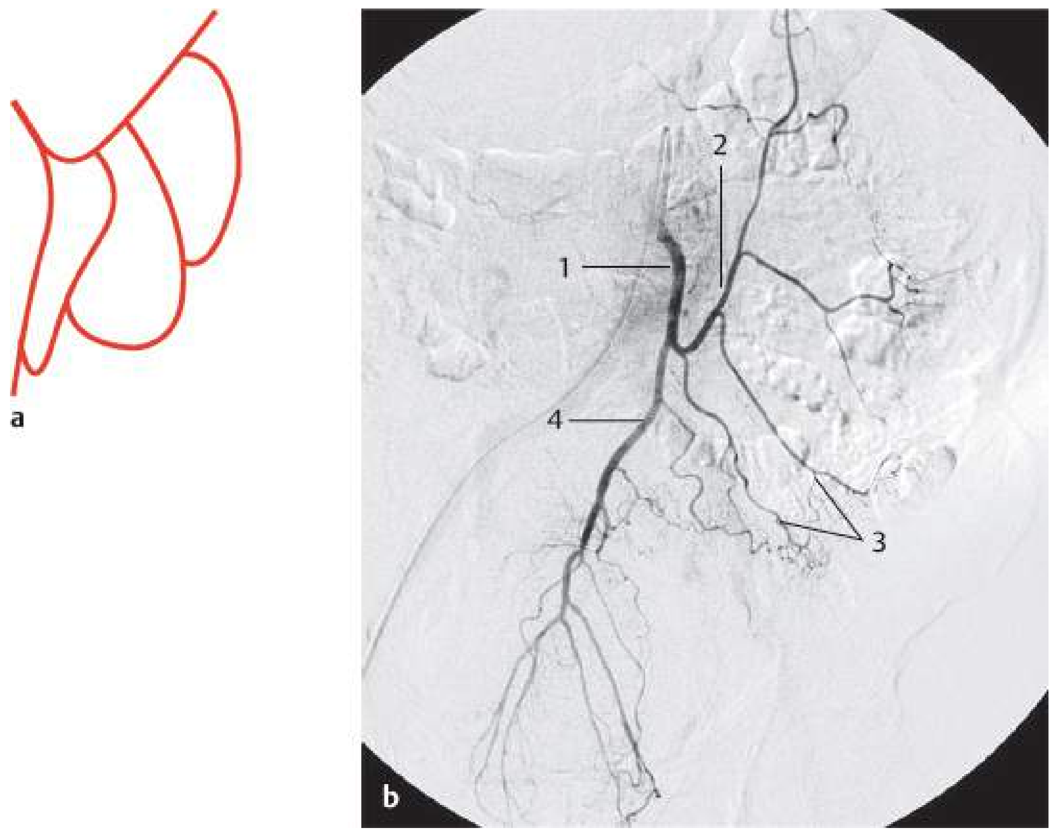

Fig. 22.5 Bifurcation of the main stem of the inferior mesenteric artery; the sigmoid arteries originate mainly from the left colic artery (~9%). Schematic (**a**) and DSA (**b**). **1** Inferior mesenteric artery; **2** left colic artery; **3** sigmoid branches; **4** superior rectal artery.

22.2 Middle Colic or Accessory Middle Colic Artery Originates from the Inferior Mesenteric Artery (10%)

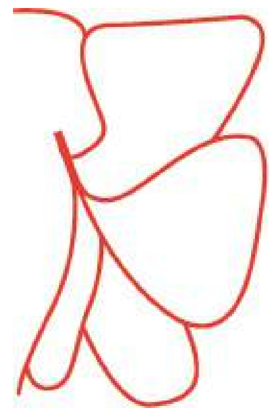

Fig. 22.6 (Accessory) middle colic artery from the main stem of the inferior mesenteric artery (5%). Schematic.

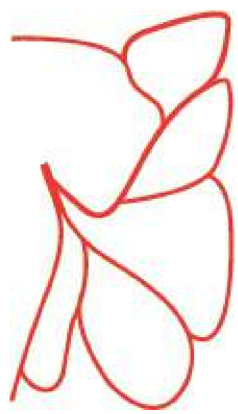

Fig. 22.7 (Accessory) middle colic artery from the left colic artery (5%). Schematic.

22.3 Rare Situations (1%)

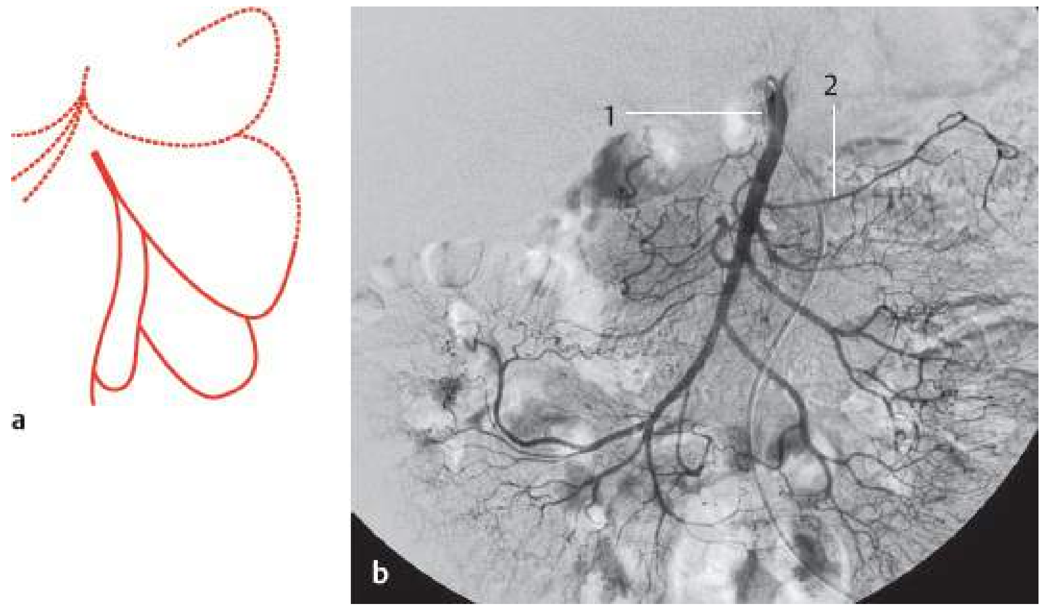

Fig. 22.8 Left colic artery is absent or originates from the superior mesenteric artery (1%). Schematic (**a**) and DSA (**b**), both with left colic artery originating from the superior mesenteric artery. **1** Superior mesenteric artery; **2** left colic artery.

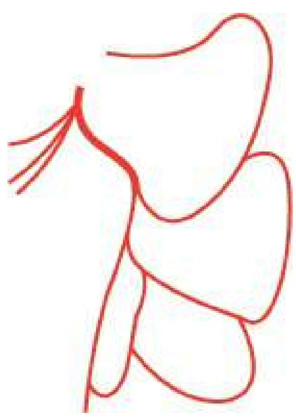

Fig. 22.9 Inferior mesenteric artery arises from the superior mesenteric artery (<0.1%). Schematic.

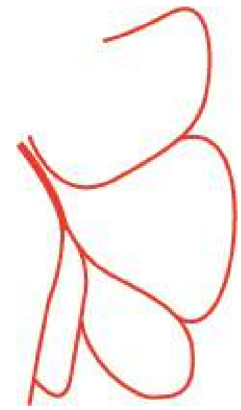

Fig. 22.10 Two inferior mesenteric arteries with the left colic artery as a direct branch of the aorta (<0.1%). Schematic.

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23 Internal Iliac Artery

K.I. Ringe, S. Meyer

The parietal and visceral arteries branch from the internal iliac artery in numerous ways.[1–10] It is difficult to classify these types according to embryological development or by practical features. According to embryological development, the umbilical artery must be the main branch and the other arteries only side branches.[7] After birth, the umbilical artery is no longer important, and in approximately 0.7% of all cases one umbilical artery is absent. These anomalies are not shown in the figures. Some recent studies have described and partly summarized such cases along with the relevant literature.[11,12] The sequence of branches or trunk formations is extremely variable.[6,13,14] This situation is also complicated by the various names of these arteries in the different anatomical nomenclatures. In some clinical studies, the internal iliac artery is still called the hypogastric artery.

23.1 All Arteries Branch from One Main Stem of the Internal Iliac Artery (10%)

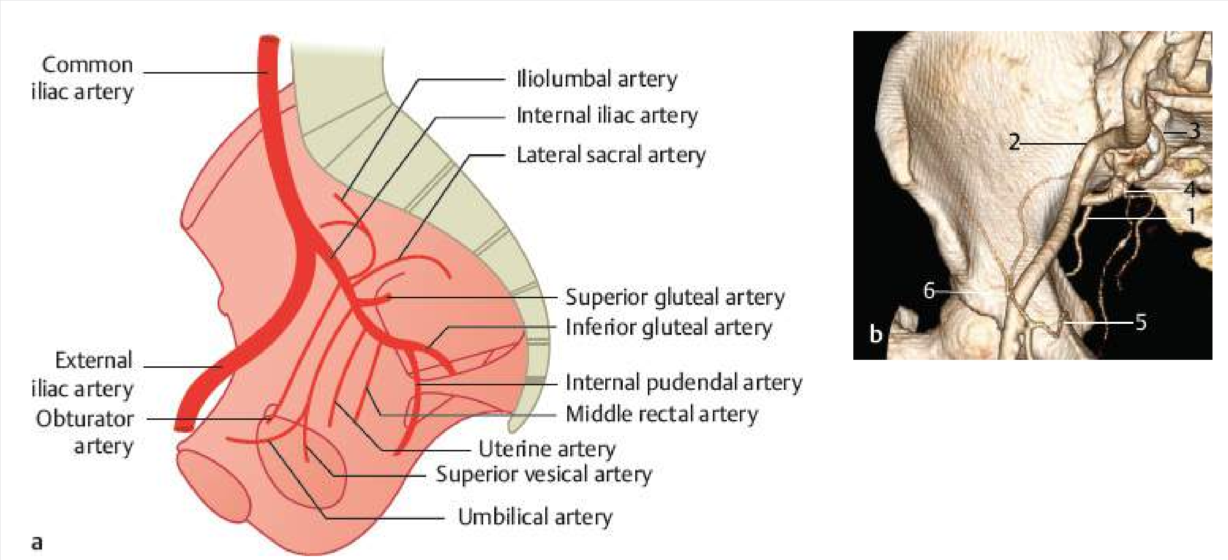

Fig. 23.1 One main stem of the internal iliac artery (10%). Schematic (**a**) and 3D VR CT (**b**). **1** Inferior gluteal artery; **2** external iliac artery; **3** internal iliac artery; **4** superior gluteal artery; **5** obturator artery; **6** epigastric artery.

23.2 The Iliac Artery Divides into Two Main Stems Which Give Off the Other Branches (60%)

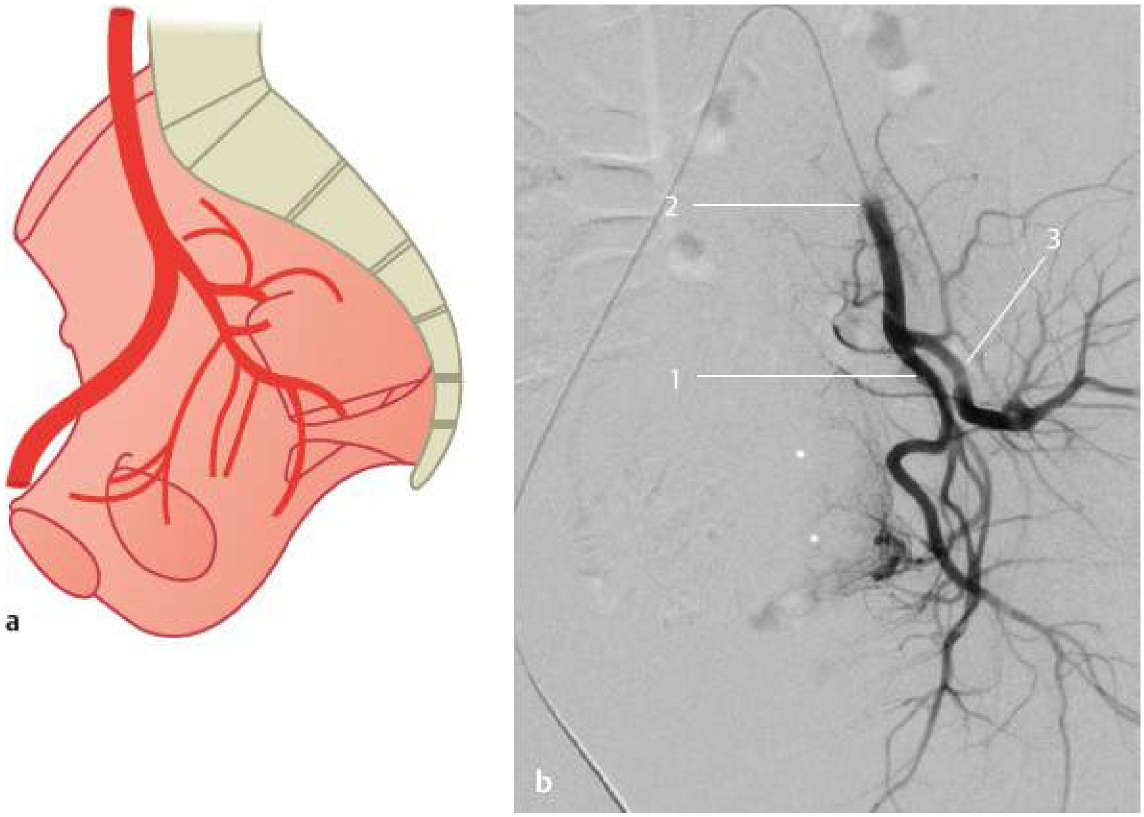

Fig. 23.2 The posterior main stem ends as the superior gluteal artery, the anterior trunk ends as the inferior gluteal and the internal pudendal arteries (35%). Schematic (**a**) and DSA (**b**). The DSA shows the left internal iliac artery dividing into two main stems which give off the other branches. The patient has uterine myoma (*) and was undergoing embolization therapy. **1** Anterior main stem; **2** internal iliac artery; **3** posterior main stem.

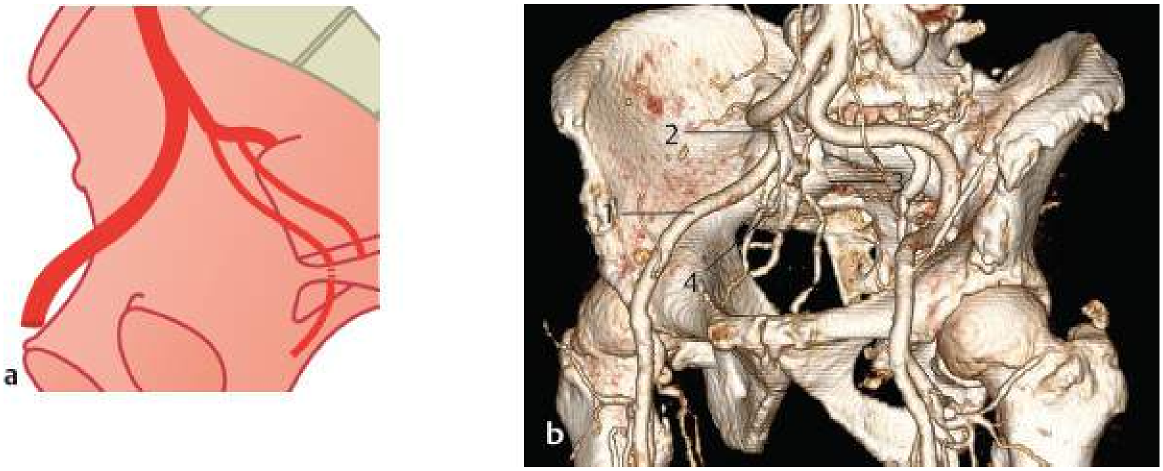

Fig. 23.3 The anterior stem ends as the internal pudendal artery, the posterior trunk divides into the superior and inferior gluteal arteries, which leave the pelvis through the suprapiriform and infrapiriform foramen (12%). Schematic (**a**) and oblique coronal 3D VR CT (**b**) of the right internal iliac artery. **1** External iliac artery; **2** internal iliac artery; **3** posterior stem; **4** anterior stem.

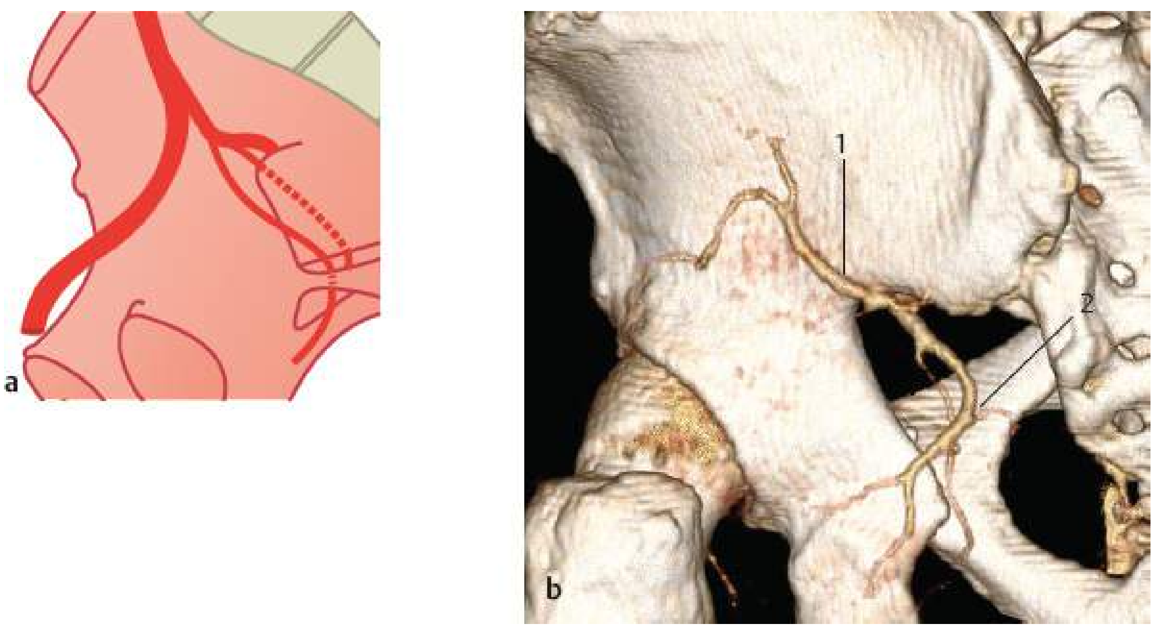

Fig. 23.4 Same as Fig. 23.3, but the posterior stem divides after leaving the pelvis through the suprapiriform foramen. The inferior gluteal artery then runs dorsally to the piriform muscle (12%).

Schematic (**a**) and 3D VR CT, posterior view (**b**). **1** Superior gluteal artery; **2** inferior gluteal artery.

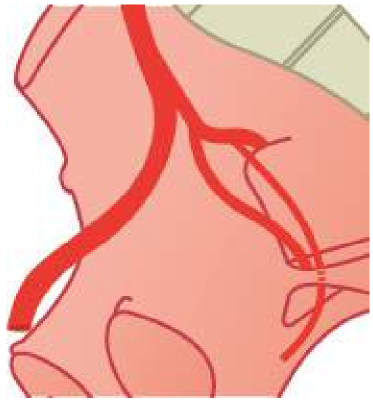

Fig. 23.5 The anterior stem ends as the inferior gluteal artery; the terminal branches of the posterior stem are the superior gluteal and the internal pudendal arteries (1%). Schematic.

23.3 The Internal Iliac Artery Divides into Three Stems Which Give Off All Other Branches (20%)

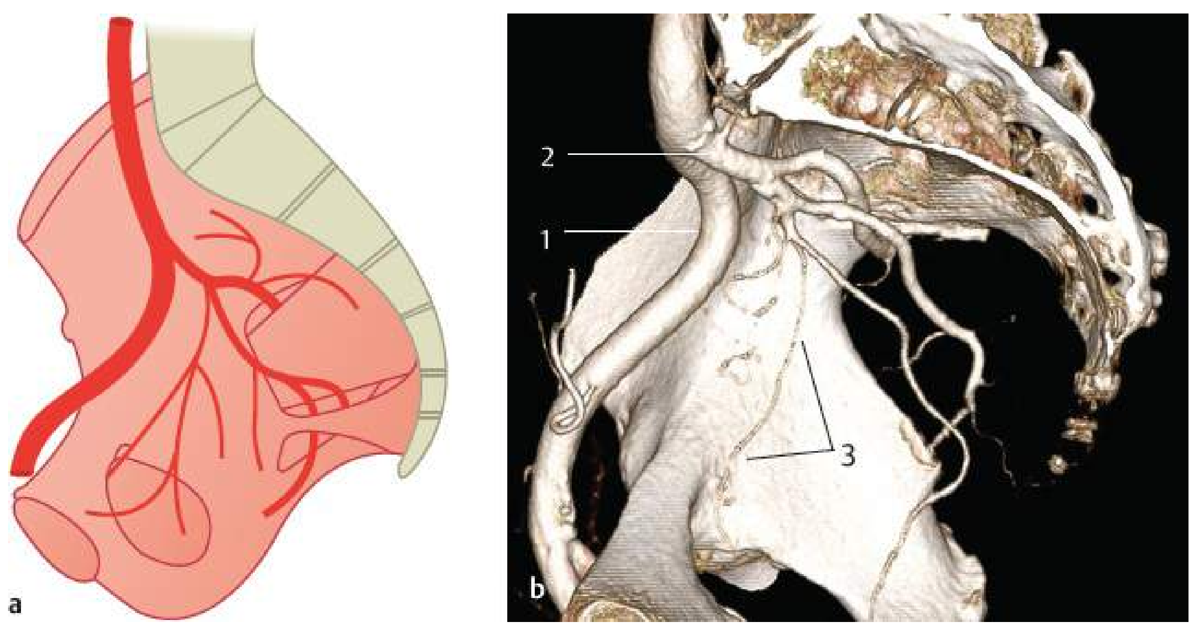

Fig. 23.6 The internal iliac artery divides into three stems which give off all other branches (20%). Schematic (**a**) and 3D VR CT (**b**). **1** External iliac artery; **2** internal iliac artery; **3** obturator artery.

23.4 The Internal Iliac Artery Divides into Four or More Stems Which Branch to Form the Other Arteries (10%)

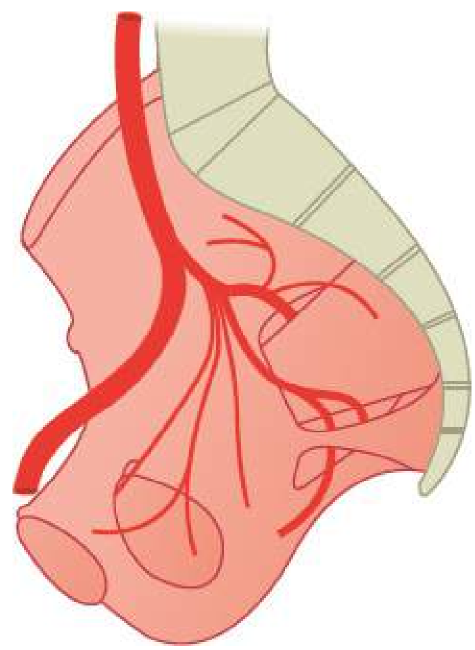

Fig. 23.7 The internal iliac artery divides into four or more stems which branch to form the other arteries (10%). Schematic.

23.5 Origin of the Internal Iliac Artery

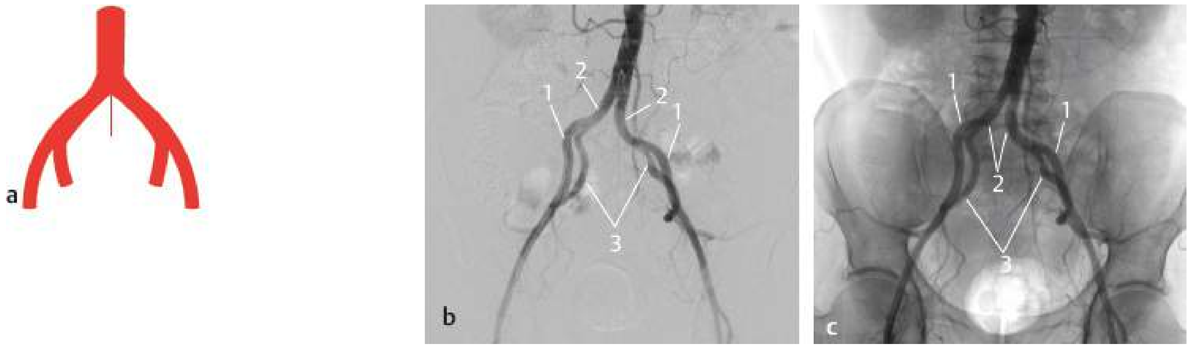

Fig. 23.8 The common iliac artery divides into the internal and external iliac arteries (>99%). Schematic (**a**) as well as subtracted (**b**) and nonsubtracted (**c**) DSA. The DSA shows the internal iliac artery originating from the common iliac artery on both sides. **1** External iliac artery; **2** common iliac artery; **3** internal iliac artery.

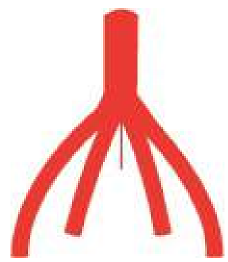

Fig. 23.9 The common iliac artery is absent or very short. The internal and external iliac arteries arise from the aorta (<1%). Schematic.

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24 Arteries of the Female Genital Tract

T. Kroencke

The internal female genital organs are supplied by the uterine and ovarian arteries. The origin of the ovarian artery is shown in Chapter 12 and that of the uterine artery in the chapter on the internal iliac artery (Chapter 23). Both arteries anastomose by branches along the uterine tube. The ovary seems to be supplied either by the ovarian artery or by the ovarian branch of the uterine artery, or by both. Operations on the uterine tube can disturb the blood flow in these branches. There are systematic studies on anomalies in the course and the size of the anastomosing branch between the ovarian and uterine arteries. With the increasing number of uterine artery embolization for treatment of fibroids, ovarian artery-to-uterine artery anastomoses have been studied as a potential source of treatment failure and nontarget embolization.[1–11]

24.1 “Normal” Situation as Described in Textbook (>90%)

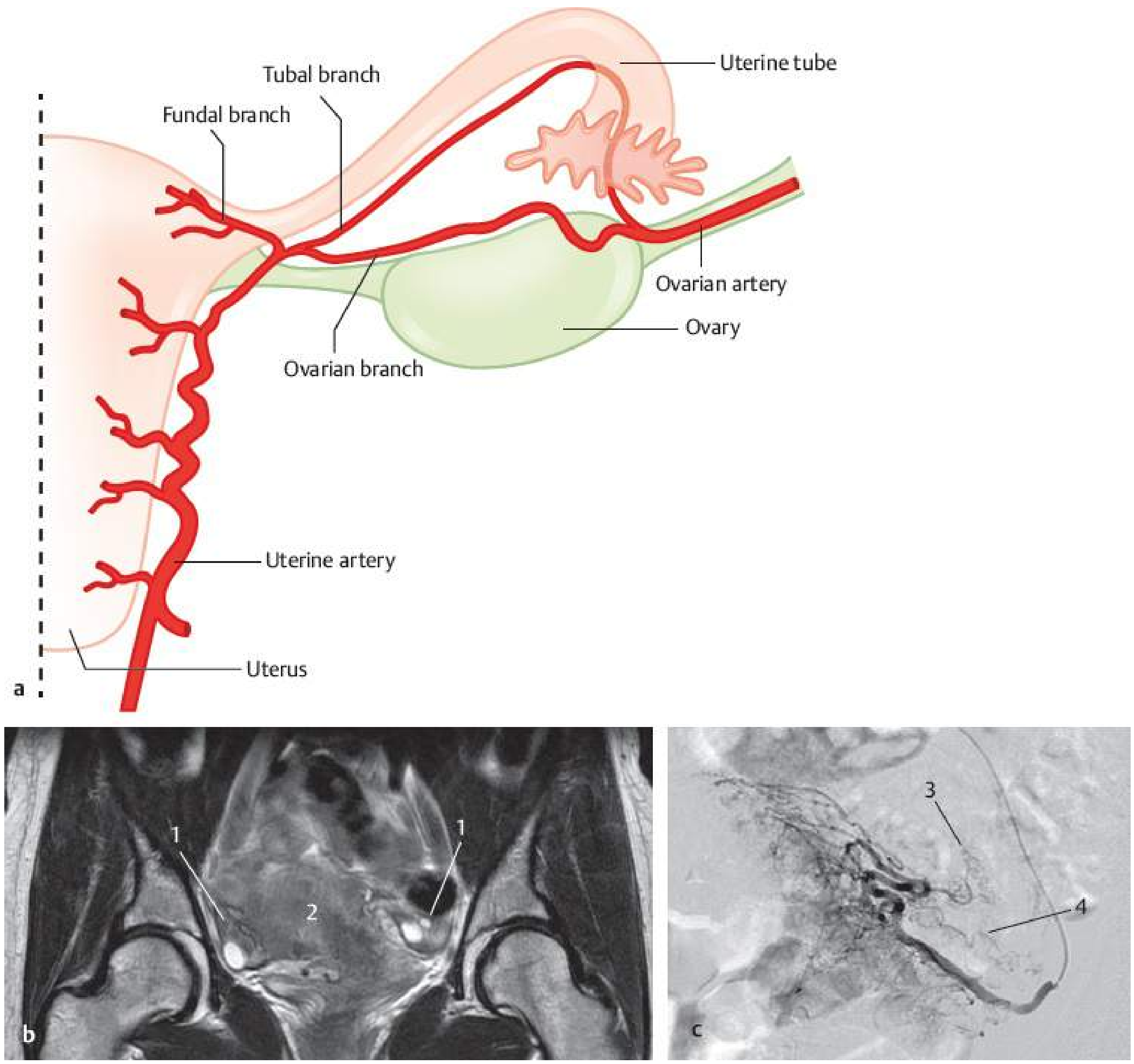

Fig. 24.1 “Normal” situation as described in textbooks (>90%). Schematic (**a**), T2-weighted coronal MRI (**b**), and selective angiography of the left uterine artery (**c**). **1** Ovary; **2** uterus; **3** ovarian branch; **4** tubal branch.

24.2 Blood Supply of the Fundus of the Uterus

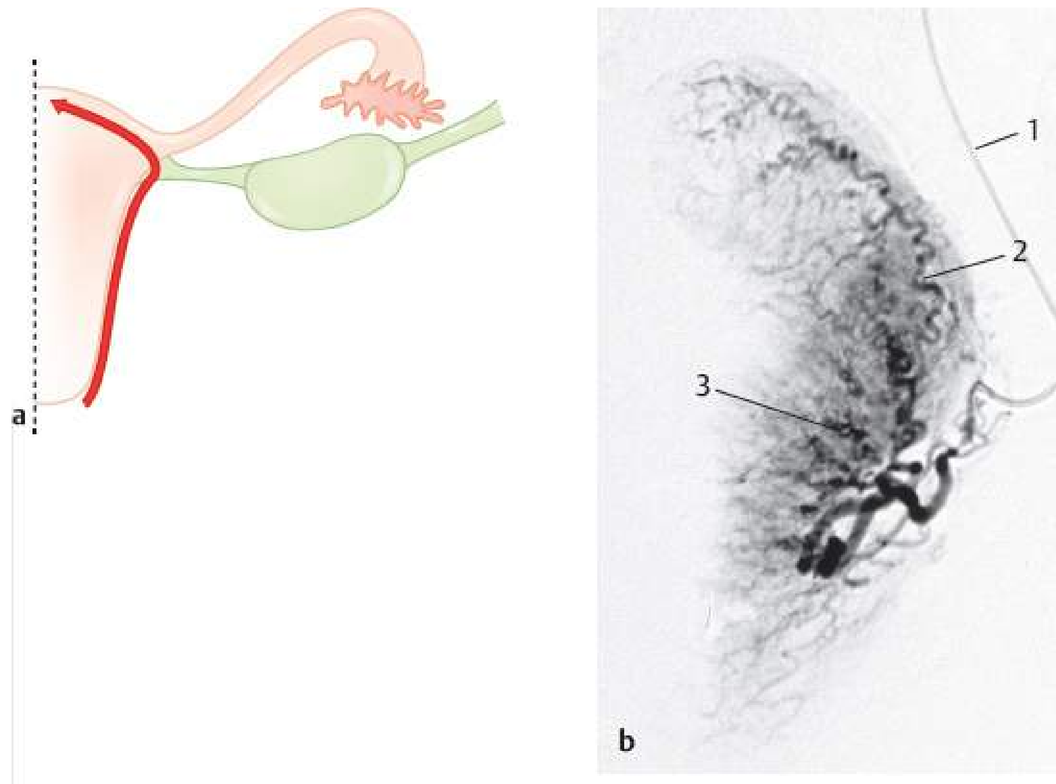

Fig. 24.2 Uterine artery (90%). Schematic (**a**) and selective angiography of the uterine artery (**b**). **1** Angiographic catheter; **2** fundal branch of the uterine artery; **3** arcuate artery.

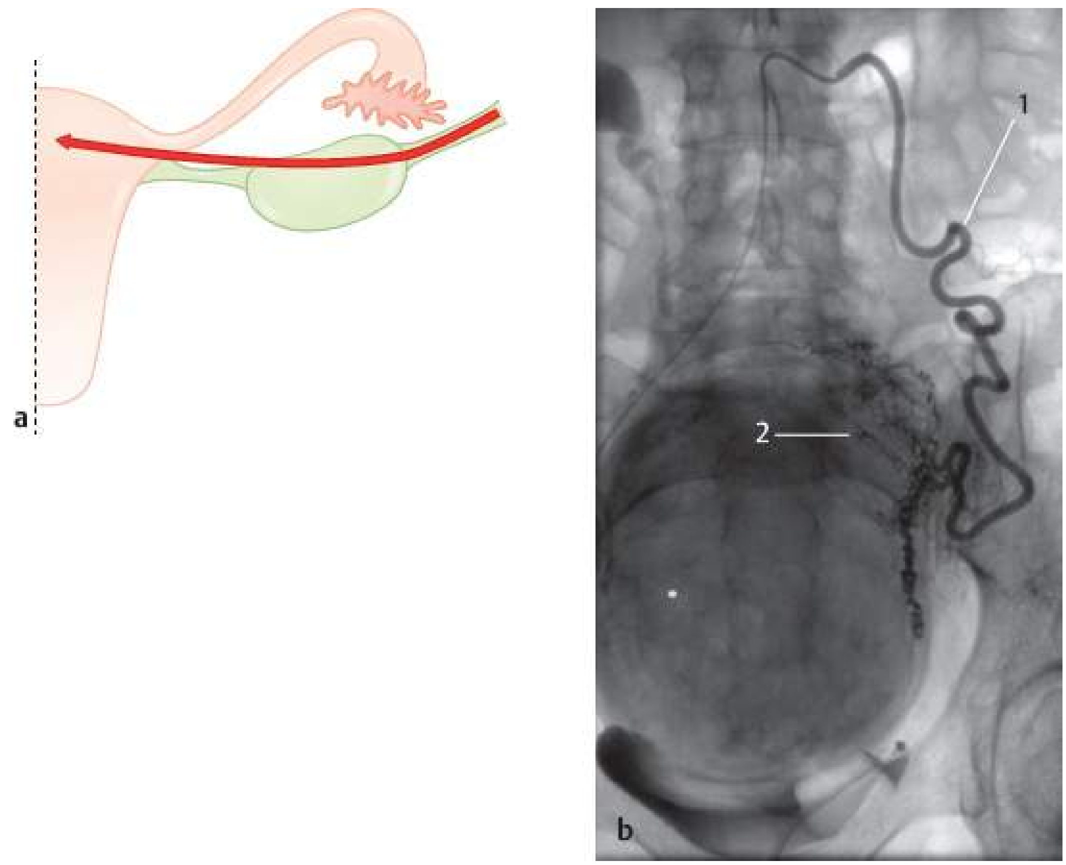

Fig. 24.3 Branches of the ovarian artery (10%). Schematic (**a**) and selective angiography of the ovarian artery post uterine artery embolization (opacification of fibroid) (**b**). **1** Ovarian artery; **2** ovarian artery terminating as fundal branches; uterine fibroid (*).

24.3 Blood Supply of the Ovary

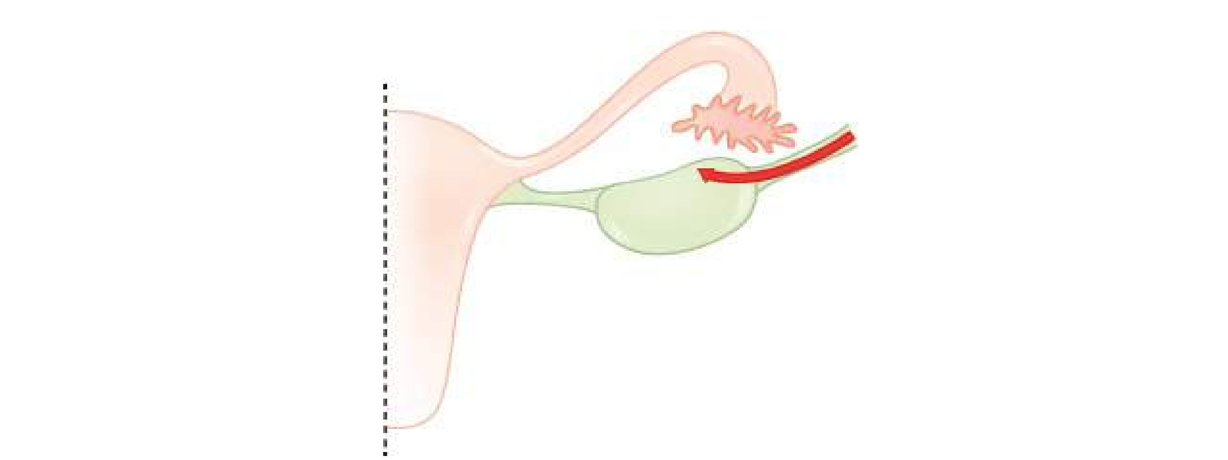

Fig. 24.4 By the ovarian artery (40%). Schematic.

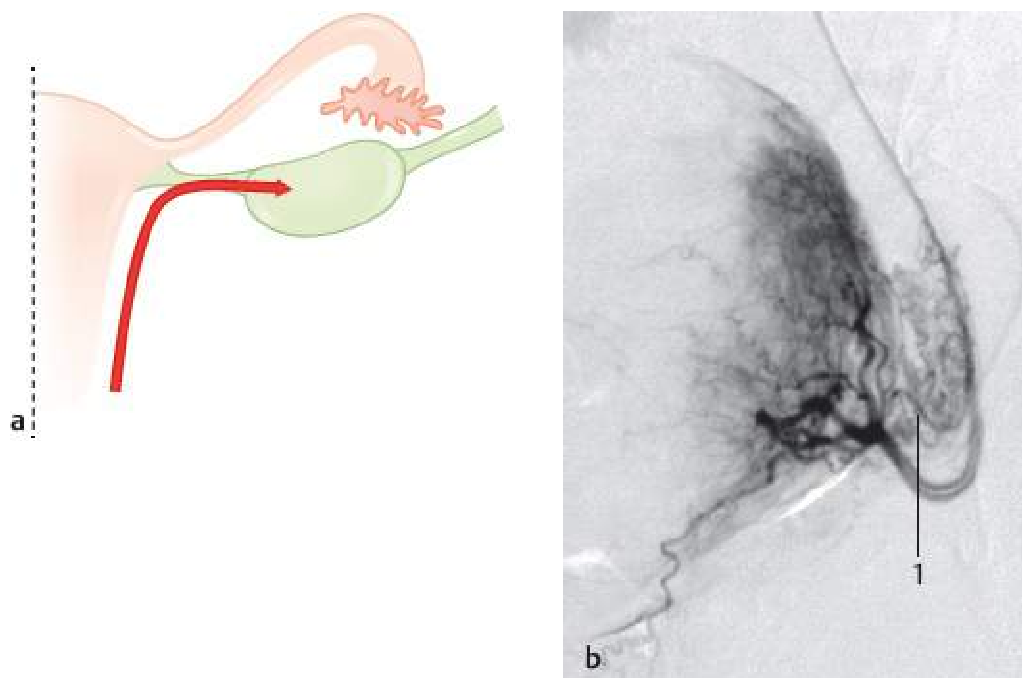

Fig. 24.5 Ovarian branch of the uterine artery (4%). Schematic (**a**) and selective angiography (**b**). **1** Ovarian branch of the uterine artery.

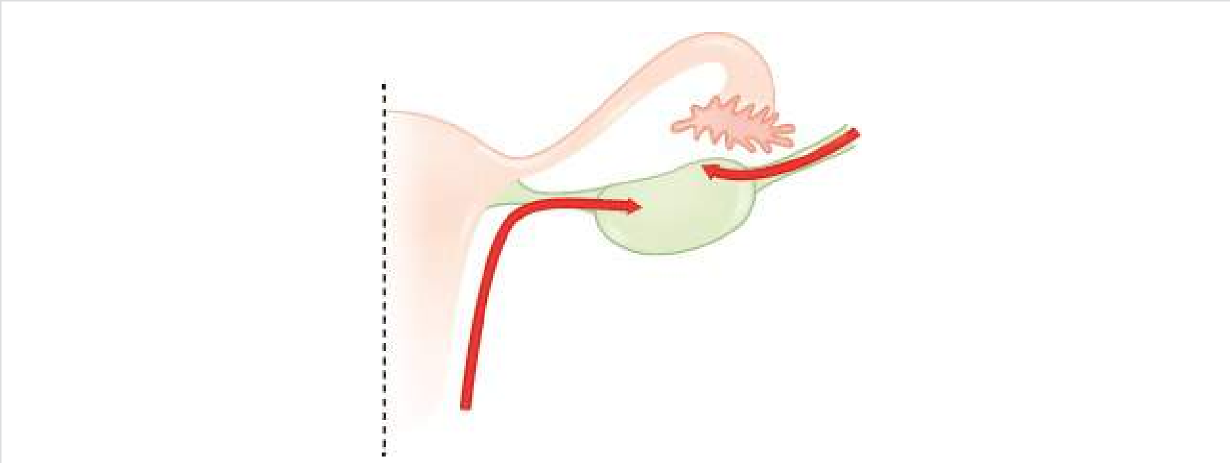

Fig. 24.6 Both the ovarian and uterine arteries supply the ovary (56%). Schematic.

24.4 Blood Supply of the Uterine Tube

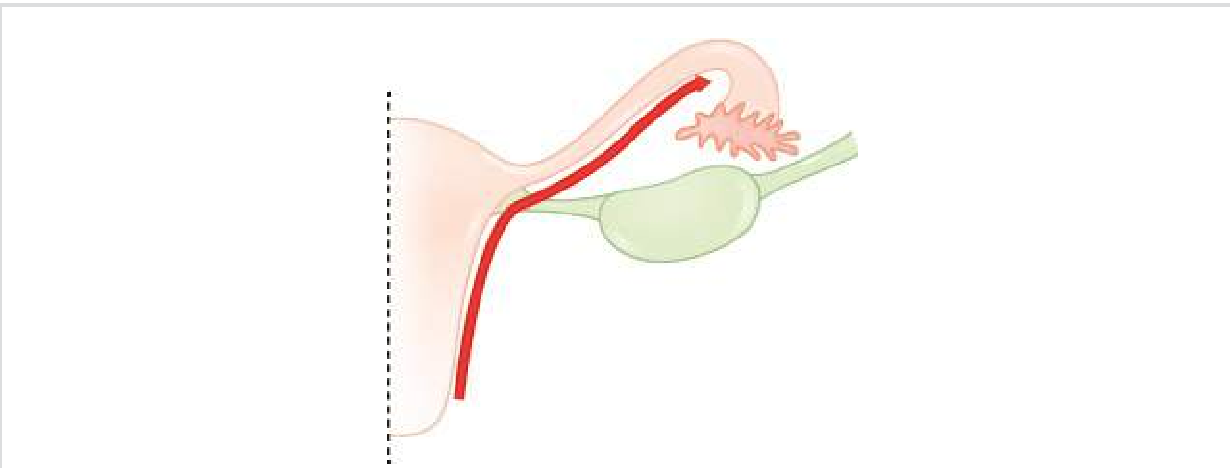

Fig. 24.7 Tubal branch of the uterine artery (60%). Schematic.

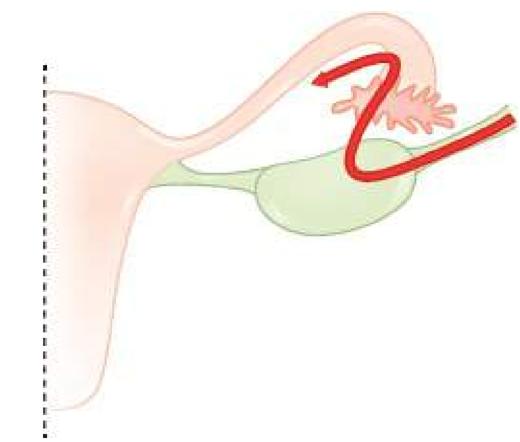

Fig. 24.8 Tubal branch of the ovarian artery (30%). Schematic.

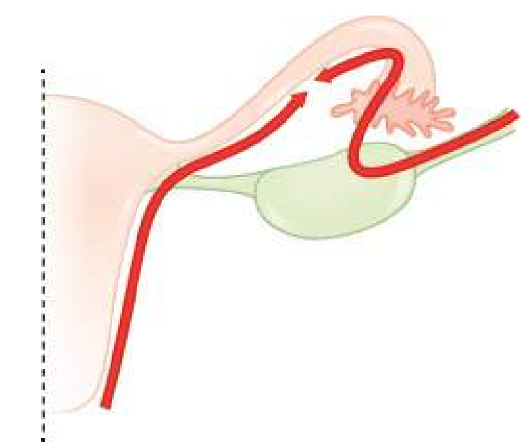

Fig. 24.9 Both the ovarian and uterine arteries supply the tube (10%). Schematic.

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25 Obturator Artery

K.I. Ringe

The number of its variations increases considerably if all the different types of branching of the internal iliac artery are considered.[1–7] To avoid confusion, the most common type, that is, the division of the internal iliac artery into two stems (Chapter 23), is taken as a basis for these figures. The percentages for the different types are averages. Accessory obturator arteries are not outlined. Small accessory branches or different origins with a trunk formation are very common. In such cases, arteries can cross the obturator nerve,[7] which can be of relevance during pelvic lymph node dissection. The obturator artery supplies the muscles of the inner wall of the pelvis (obturator internus, psoas muscle) and has a pubic branch to the symphysis, which anastomoses with the obturator branch of the inferior epigastric artery. In **Fig. 25.8**, this anastomosis is very prominent and in **Fig. 25.7** the inferior epigastric artery alone feeds the obturator artery. A major branch between the inferior epigastric artery and the obturator artery was formerly called the “arteria corona mortis.” This artery was sometimes lacerated during herniotomies, and because such arterial bleeding was difficult to staunch in former times, it could prove fatal. If it is not recognized in pelvic fractures, it may result in untreated arterial bleeding.[8] After passing the obturator canal, the obturator artery divides into the anterior branch to the adductor muscles and the posterior branch to the hip joint.[9]

25.1 Origin from the Internal Iliac Artery (75%)

A small acetabular branch reaches the head of the femur through the ligament of the head of the femur. Normally this branch is not able to supply sufficient blood to the head of the femur in cases of an epiphysiolysis. Racial differences have been discovered in connection with the origin of the obturator artery from the external iliac artery. The data given here are derived from studies on North Americans and Europeans; however, in Japan the frequency of this anomaly seems to be halved.[1] In females, this anomaly is assumed to be more frequent. The obturator artery can also originate from the femoral artery; it then turns backward through the lacuna vasorum into the pelvis.[10] The anastomoses between the obturator artery and the inferior epigastric and other arteries of the leg are sometimes of importance when the external iliac artery is occluded in atherosclerosis.

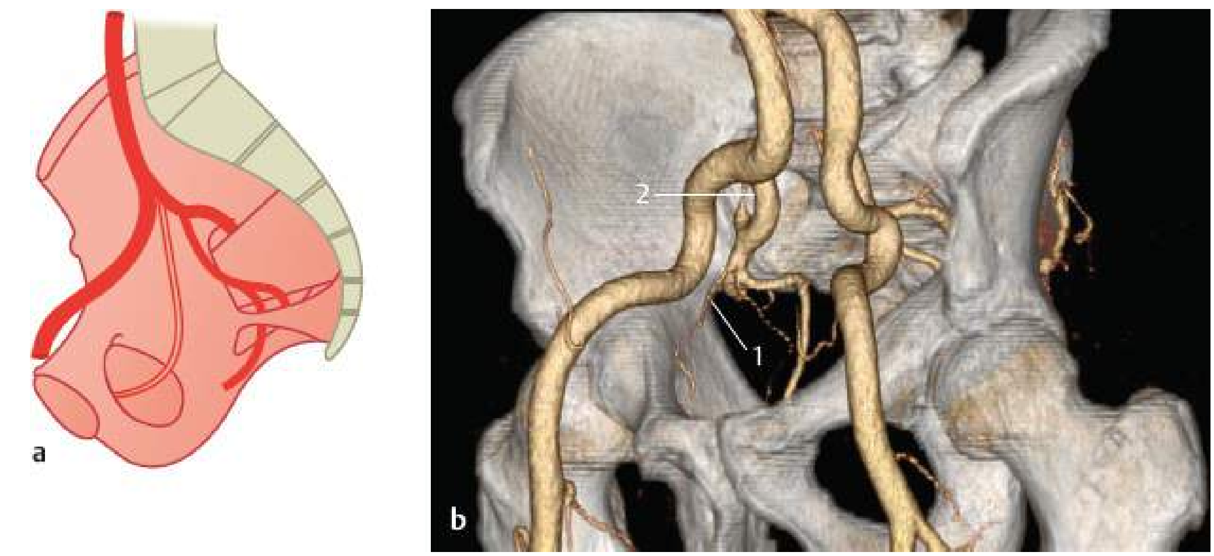

Fig. 25.1 The obturator artery branches from the stem of the internal iliac artery (15%). Schematic (**a**) and coronal oblique 3D VR CT (**b**). The CT shows the obturator artery branching from the stem of the internal iliac artery on the right side. **1** Obturator artery; **2** internal iliac artery.

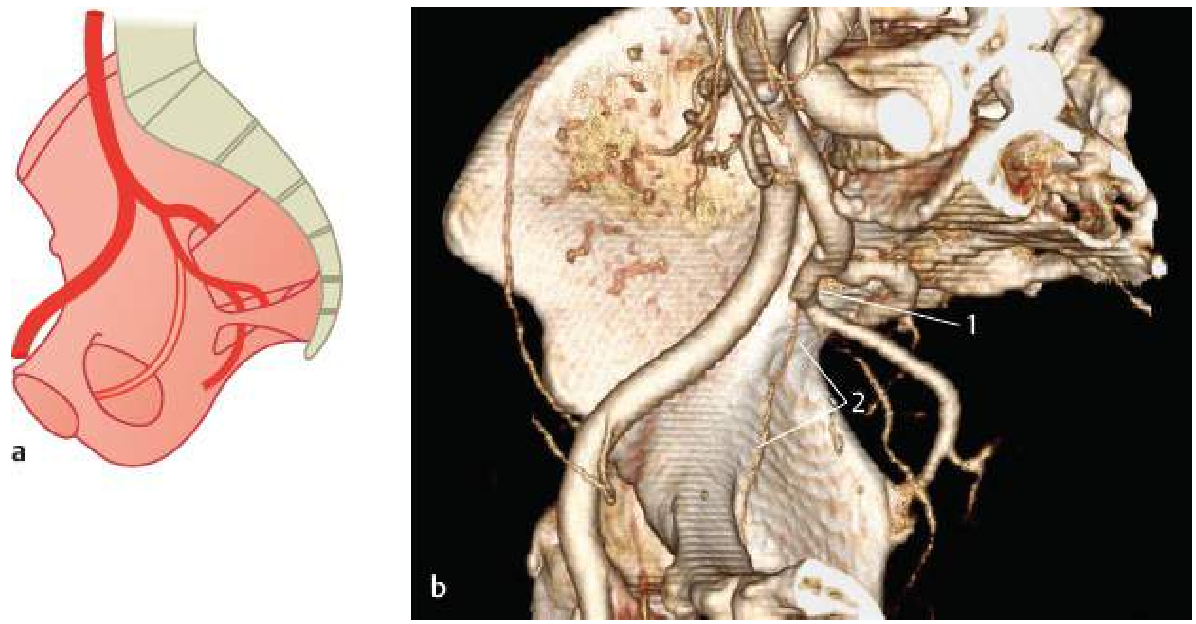

Fig. 25.2 The obturator artery branches from the anterior stem of the internal iliac artery (25%). Schematic (**a**) and coronal oblique 3D VR CT (**b**). The CT shows the obturator artery branching from the anterior stem of the internal iliac artery on the right side. **1** Anterior stem; **2** obturator artery.

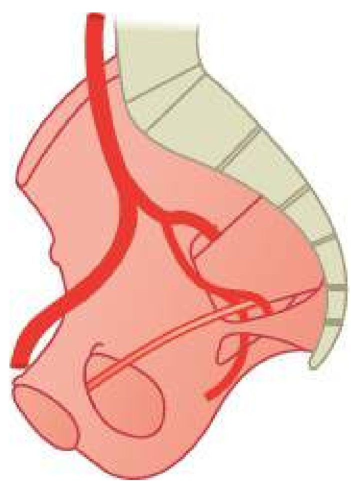

Fig. 25.3 The obturator artery branches from the inferior gluteal artery (10%). Schematic.

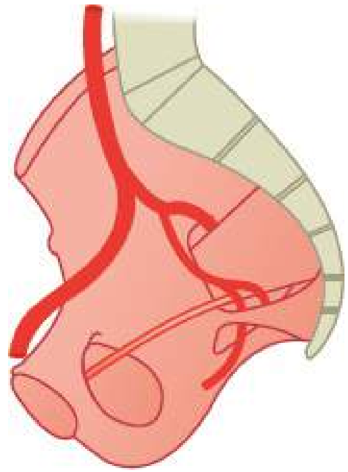

Fig. 25.4 The obturator artery branches from the internal pudendal artery (5%). Schematic.

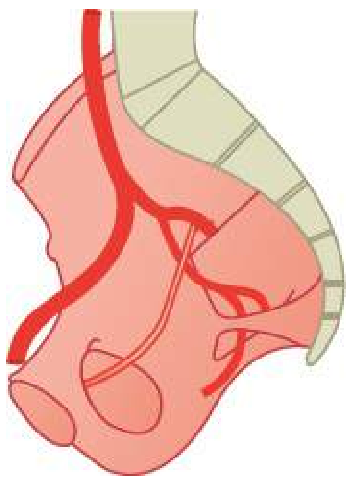

Fig. 25.5 The obturator artery branches from the dorsal stem of the superior gluteal artery (20%). Schematic.

25.2 Origin from the External Iliac Artery (25%)

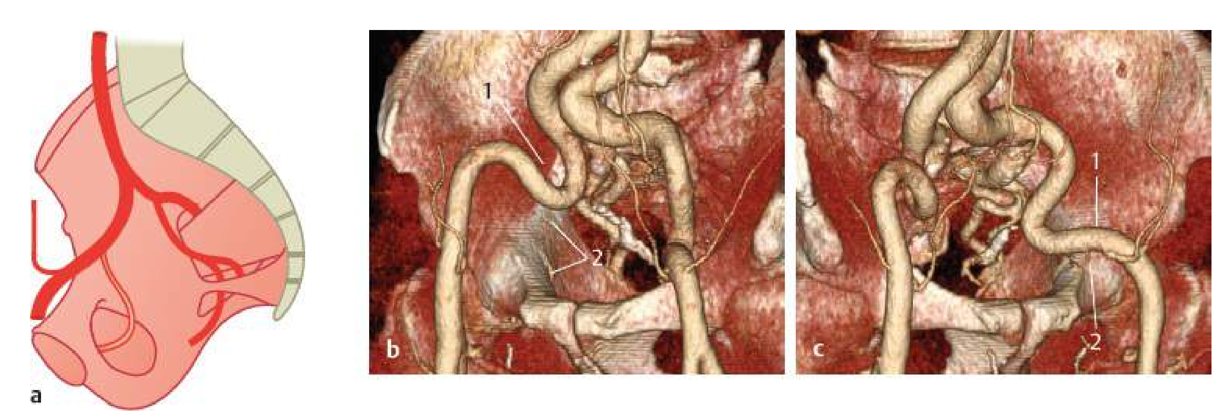

Fig. 25.6 The obturator artery branches directly from the external iliac artery (2%). Schematic (**a**), and coronal oblique 3D VR CT of the right (**b**) and left (**c**) obturator artery branching from the external iliac artery. **1** External iliac artery; **2** obturator artery.

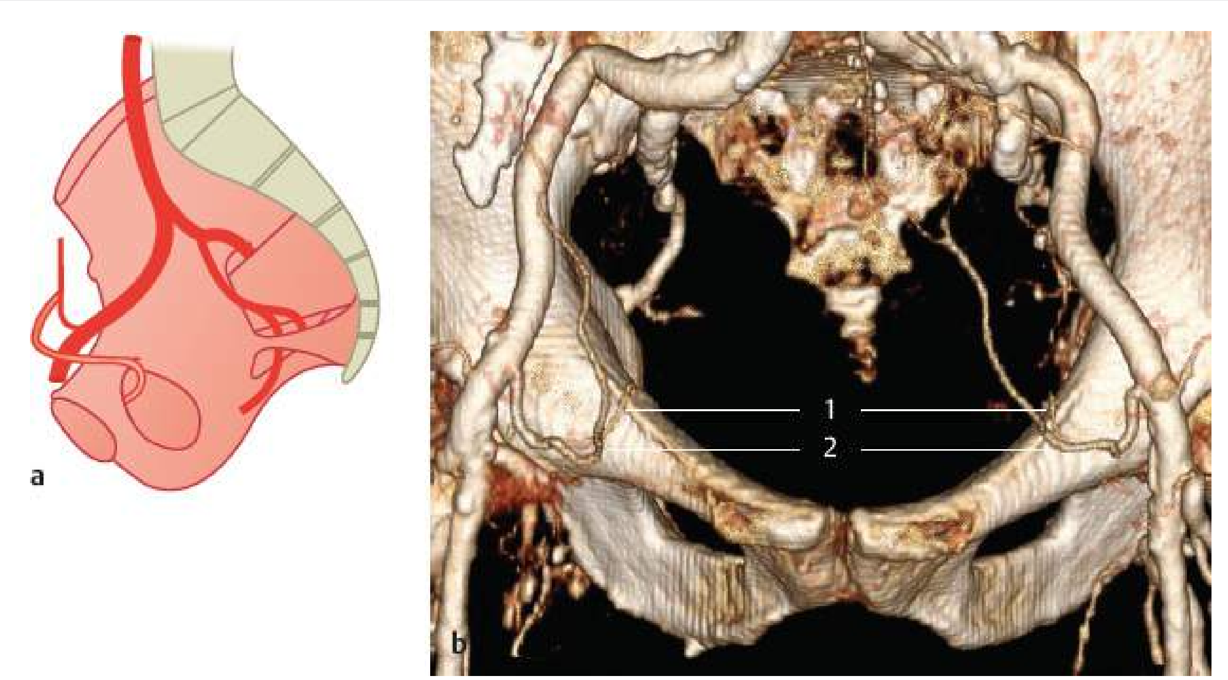

Fig. 25.7 The obturator artery is a branch of the inferior epigastric artery (22%). Schematic (**a**) and coronal oblique 3D VR CT (**b**). The CT shows the obturator artery branching off the inferior epigastric artery on both sides. **1** Obturator artery; **2** epigastric artery.

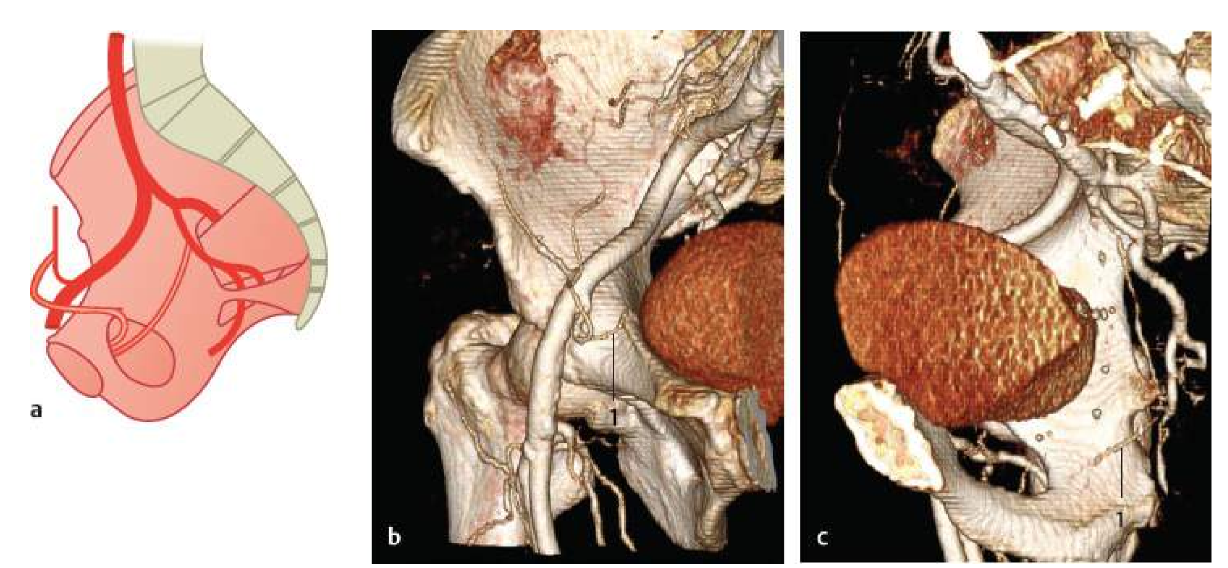

Fig. 25.8 The obturator artery originates with roots of about equal size from the external iliac and the internal iliac or its branches (1%). Schematic (**a**) and 3D VR CT, coronal (**b**) and sagittal (**c**) views. The CT shows the right obturator artery with roots from external iliac and internal iliac branches. **1** Obturator artery.

25.3 Accessory Pudendal Artery

The obturator artery usually gives off tiny branches to the area of the internal pudendal artery. In approximately 5% of all cases, these branches take over part of the blood supply of the internal pudendal artery and end as the posterior or deep artery of the penis or clitoris.[1] Such a branch is then called an accessory pudendal artery. In another 5%, the accessory pudendal artery arises directly from the internal iliac artery or the initial part of the internal pudendal artery.[1,11,12] The incidence of accessory pudendal arteries varies from 4 to 70% depending on the means of identification. There has been an increasing emphasis on its role in erectile dysfunction and continence following pelvic surgery.[13]

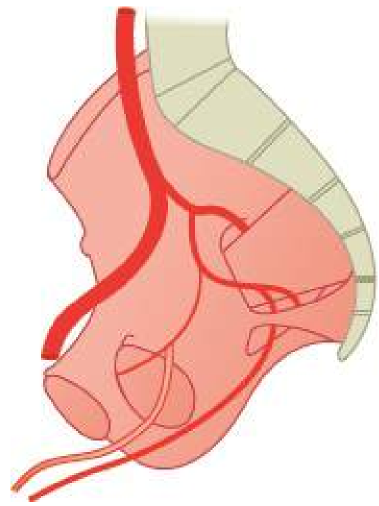

Fig. 25.9 Accessory pudendal artery (5%). Schematic.

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Part III

Lower Limbs

26 Development of the Arteries of the Lower Limb

T. Rodt, M. Lee

The arteries of the lower limbs derive from the fifth lumbar artery (Chapter 8), which forms the umbilical artery in the embryo. At the embryo stage of a crown-to-heal length of 10 mm, several side branches can already be identified: the external iliac, sciatic, superior gluteal, and internal pudendal arteries. The sciatic artery passes through the sciatic plexus and forms the main artery of the leg. It persists in most vertebrates. By contrast, in mammals the femoral artery, as the continuation of the external iliac artery, becomes the main artery for the lower limbs. Very early, anastomoses are formed between the posterior sciatic artery and the anterior femoral artery. When the main supply to the popliteal artery comes from the femoral artery, the sciatic artery regresses. Other parts of this anastomotic network are the precursor or the profunda femoris artery. The initial part of the sciatic artery remains as the inferior gluteal artery with a minute branch supplying the sciatic nerve.[1–4]

Another branch of the femoral artery is the saphenous artery, the name indicating that it follows the same course as the saphenous nerve and the great saphenous vein. This artery is connected to the arteries of the foot; its connections to the sciatic artery disappear. As some parts atrophy while others grow, the descending genicular artery and the posterior tibial artery are finally the only remnants of the saphenous artery. Whereas the peroneal artery is a remnant of the sciatic artery, the anterior tibial artery is a new branch. This complicated pattern of embryological development in the arteries of the leg explains the large number of anomalies.[1–3,5,6]

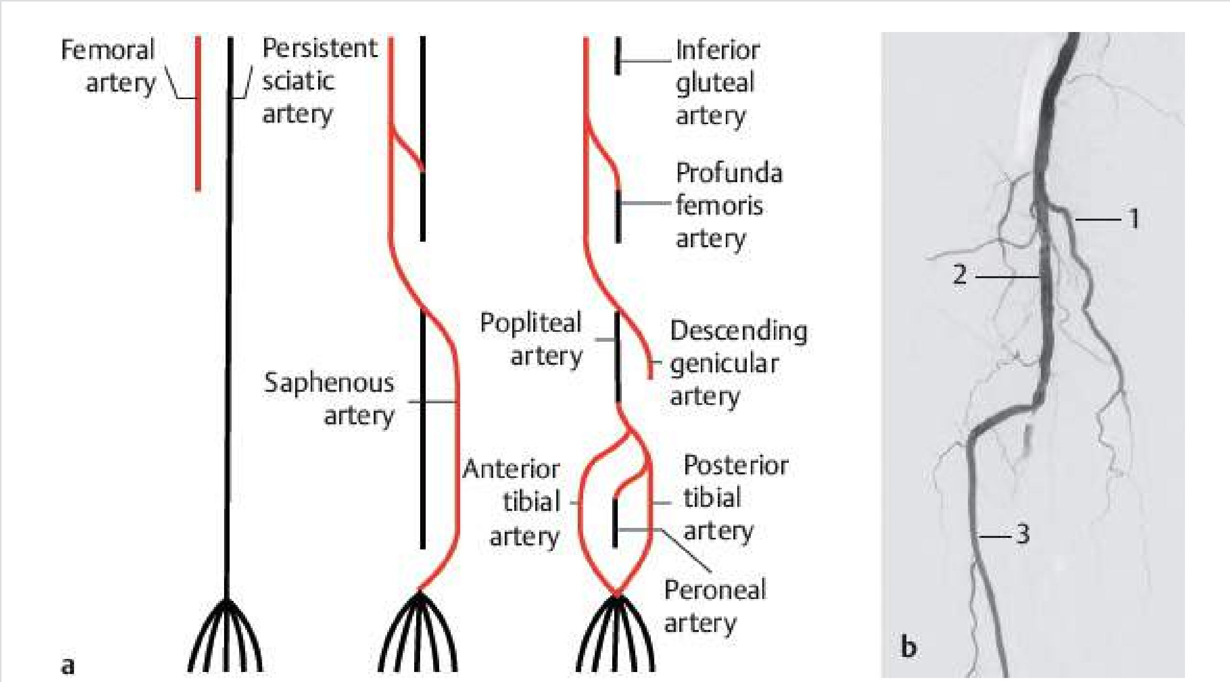

Fig. 26.1 Development of the arteries of the lower limb. Schematics (**a**) and DSA (**b**). The schematic drawings show the development of the arteries of the lower limb as described above. The DSA (**b**) shows a descending genicular artery, a remnant of the saphenous artery, popliteal artery, and anterior tibial artery. The tibioperoneal trunk is occluded. **1** Descending genicular artery;
2 popliteal artery; **3** anterior tibial artery.

26.1 Persistent Sciatic Artery

Although a rare anomaly in humans, recently many case reports have been published on the persistent sciatic artery and an increased incidence of aneurysm formation.[3,7–16] The sciatic artery, as a branch of the internal iliac artery, leaves the pelvis via the infrapiriform foramen and runs parallel to the sciatic nerve to form the popliteal artery. In such cases, the femoral artery is small and only supplies the area of the profunda femoris artery.

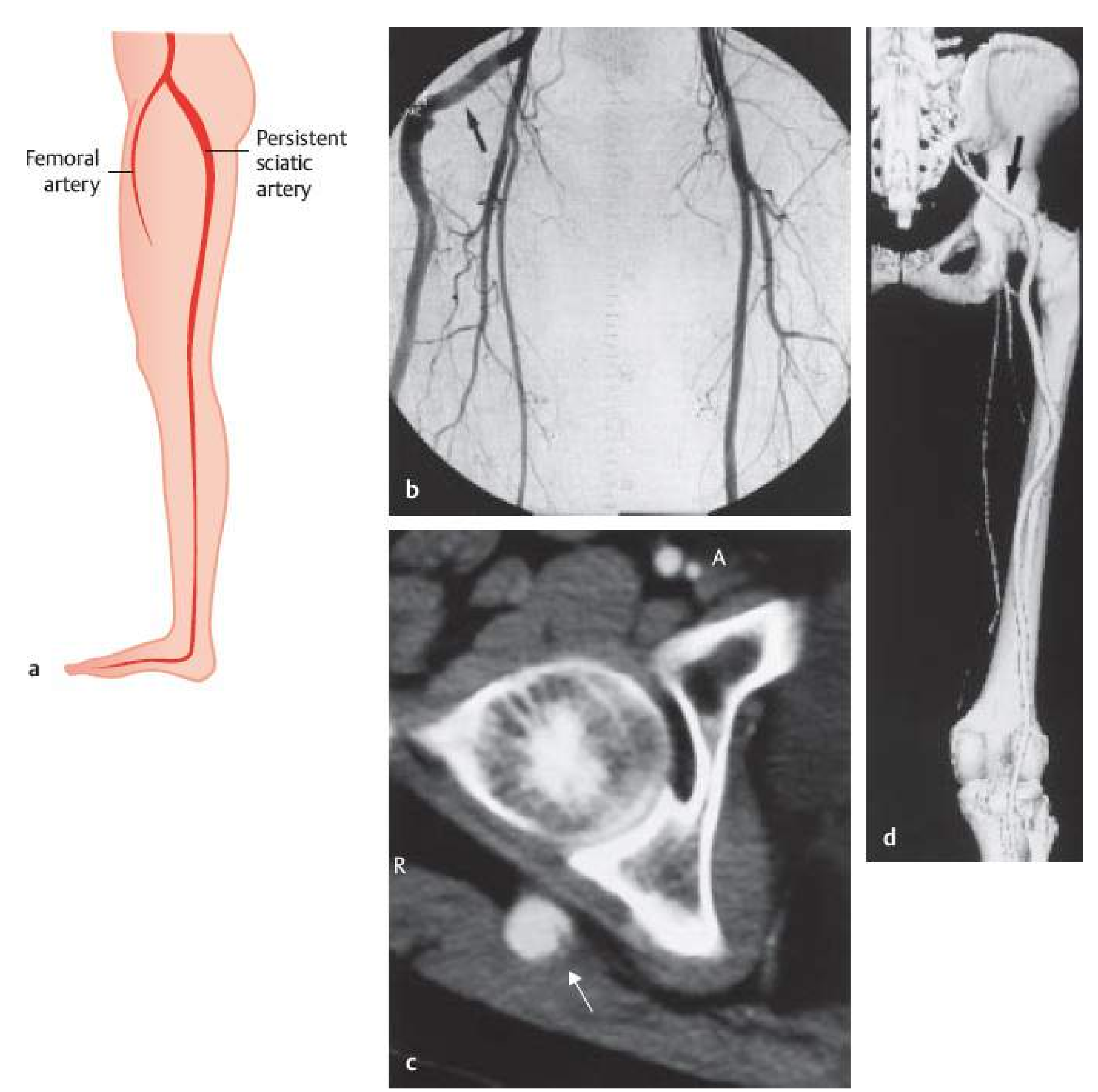

Fig. 26.2 Persistent sciatic artery (very rare). Schematic (**a**), DSA (**b**), axial CT (**c**), and posterior view 3D VR CT (**d**) showing an aneurysmatic sciatic artery (arrow in **b, c**, and **d**). (Radiographic images reproduced from Zähringer et al.[17])

26.2 Persistent Saphenous Artery

This artery is regularly found in many monkeys but surprisingly seldom in humans. It is a superficial artery running along the great saphenous vein.[18]

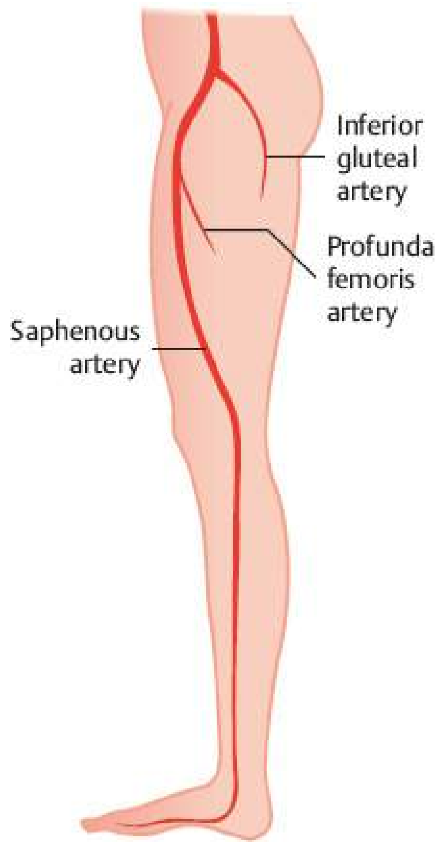

Fig. 26.3 Persistent saphenous artery (very rare). Schematic.

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27 The Profunda Femoris Artery

T. Rodt, M. Lee

Various branching patterns of the common femoral artery into the superficial femoral artery and the profunda femoris artery can be found.[1–14]

27.1 Origin and Branching Pattern

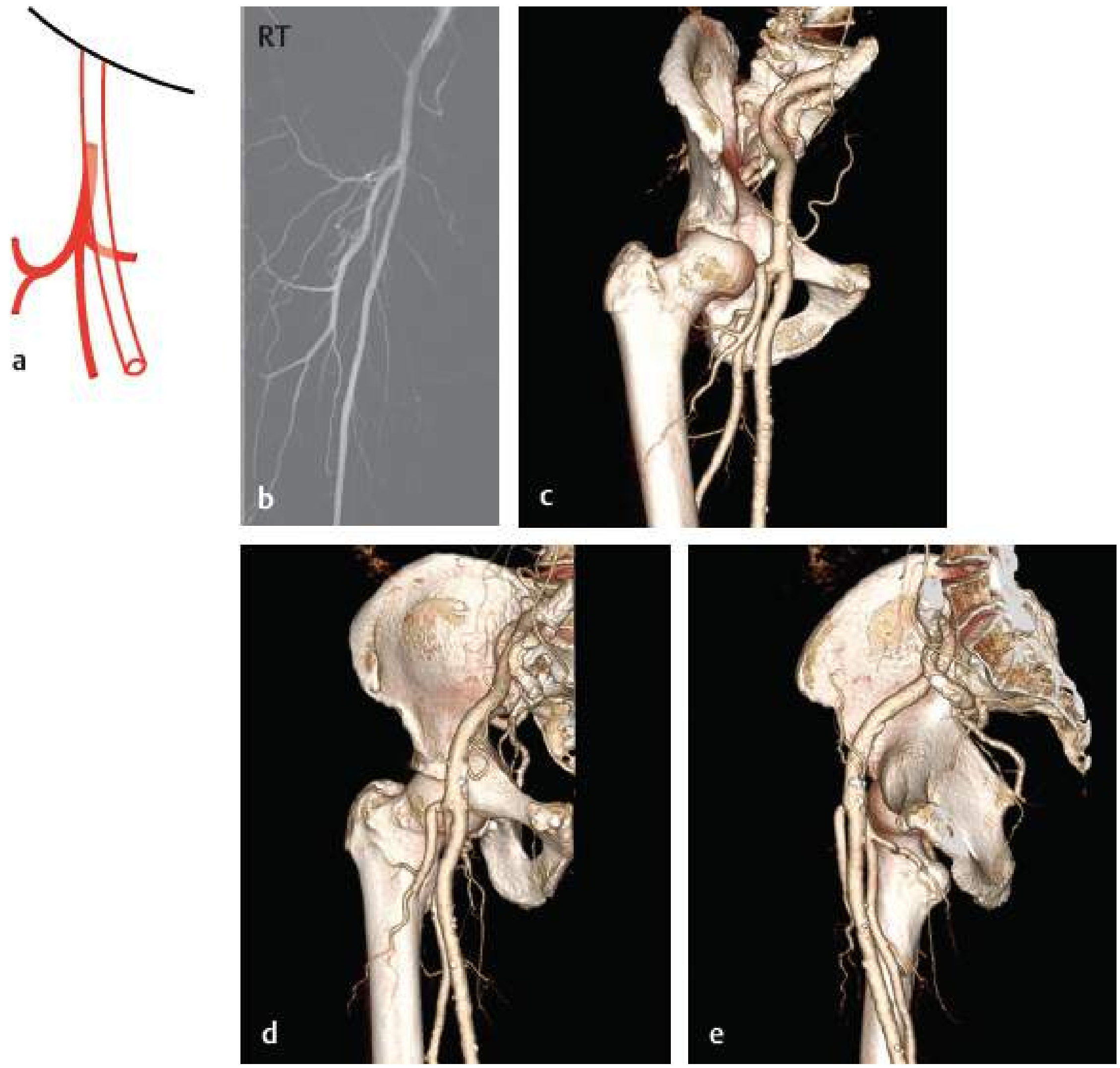

Fig. 27.1 Common trunk supplies the profunda femoris, the medial, and lateral circumflex arteries of the femur (58%). Schematic (**a**), posteroanterior (PA) DSA (**b**), and 3D-VR CT images in the right anterior oblique (RAO) view (**c**), anteroposterior (AP) view (**d**), and left anterior oblique (LAO) view (**e**).

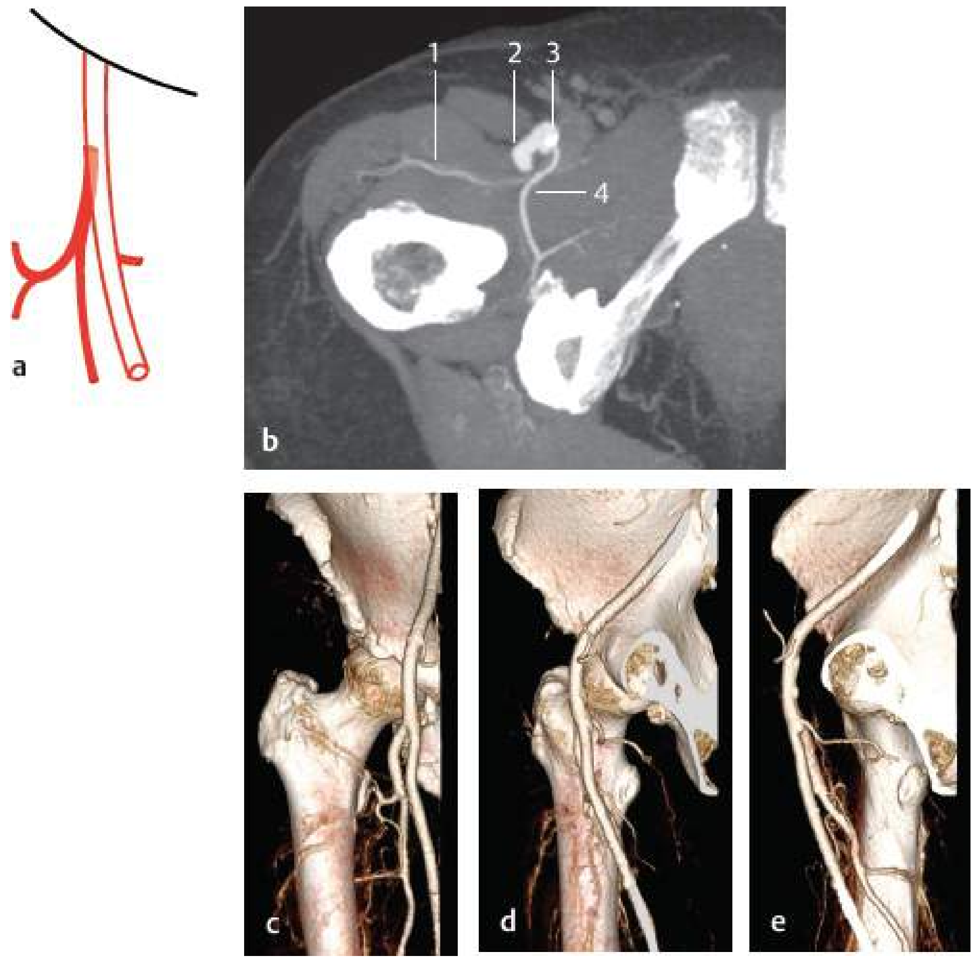

Fig. 27.2 The medial circumflex artery is a direct branch of the femoral artery (18%). Schematic (**a**), axial MIP CT (**b**), and 3D-VR CT images in the AP view (**c**), LAO view (**d**), and left lateral view (**e**). **1** Lateral circumflex artery; **2** profunda femoris artery; **3** common femoral artery; **4** medial circumflex artery.

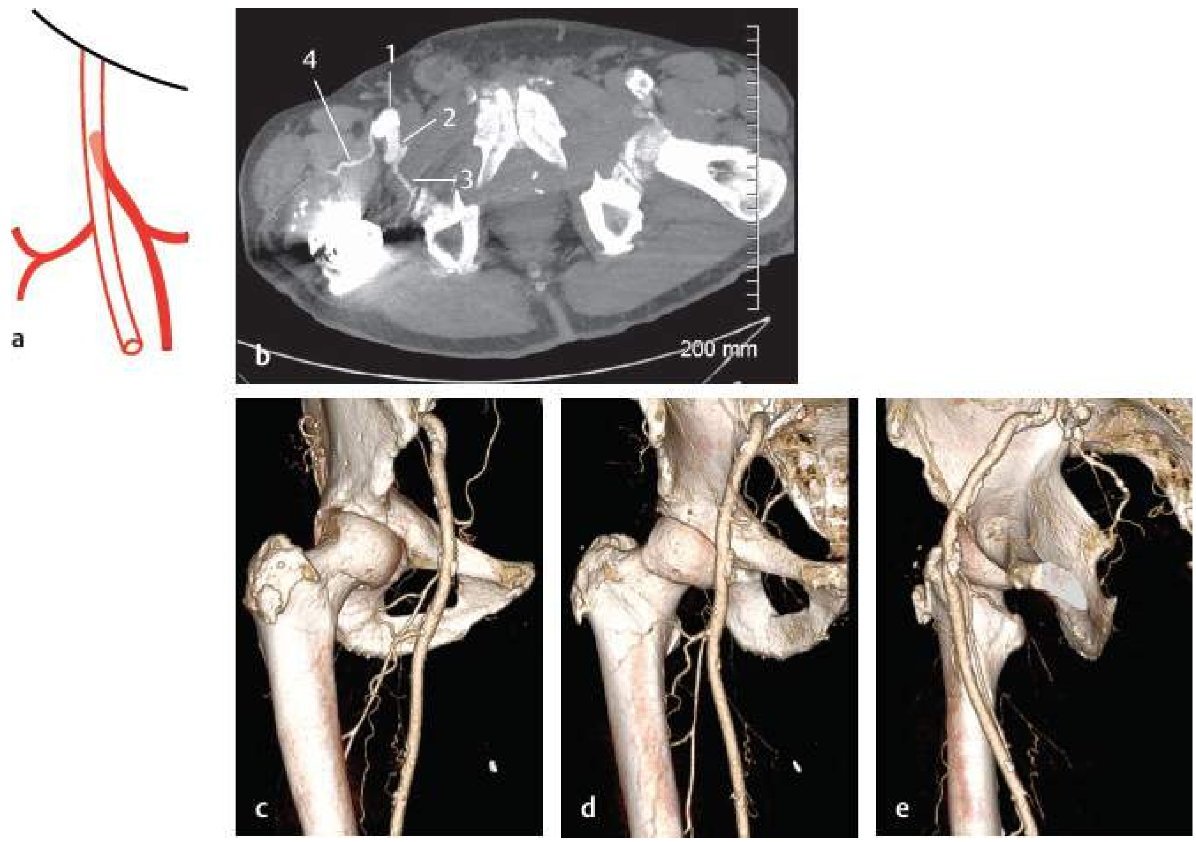

Fig. 27.3 The lateral circumflex artery is a direct branch of the femoral artery (15%). Schematic (**a**), axial MIP CT (**b**), and 3D-VR CT images in the RAO view (**c**), AP view (**d**), and LAO view (**e**). **1** Common femoral artery; **2** profunda femoris artery; **3** medial circumflex artery; **4** lateral circumflex artery.

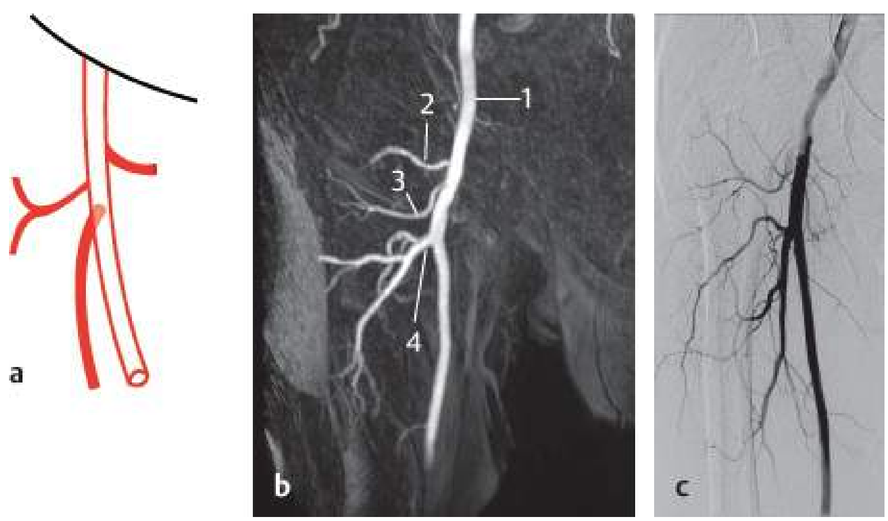

Fig. 27.4 Both circumflex arteries originate directly from the femoral artery (4%). Schematic (**a**), coronal MIP MR (**b**), and PA DSA (**c**). **1** Common femoral artery; **2** medial circumflex artery;
3 lateral circumflex artery;
4 profunda femoris artery.

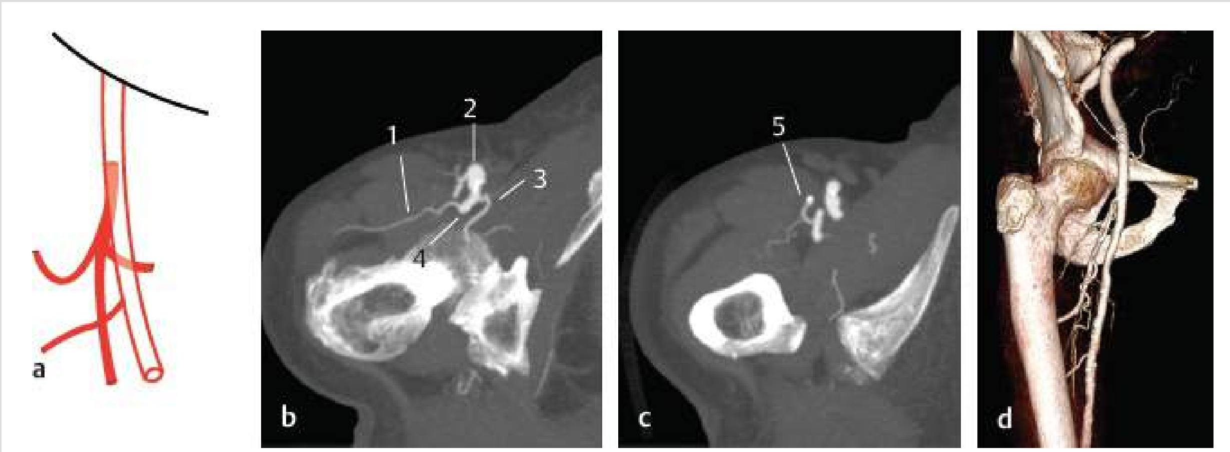

Fig. 27.5 Same as Fig. 27.1 or Fig. 27.2, but a major branch of the lateral circumflex artery comes from the femoral artery (3%). Schematic (**a**), axial MIP CT (**b,c**), and RAO projection 3D-VR CT (**d**).
1 Lateral circumflex artery;
2 common femoral artery;
3 medial circumflex artery;
4 profunda femoris artery;
5 accessory lateral circumflex branch.

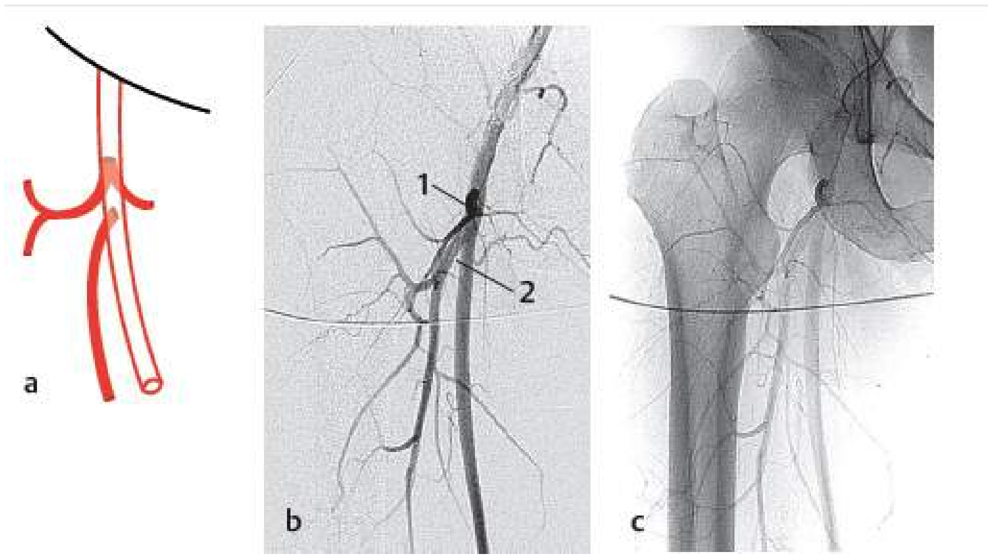

Fig. 27.6 Both circumflex arteries have a common trunk independent of the profunda femoris (1%). Schematic (**a**), PA DSA (**b**), and PA angiography (**c**).
1 Common circumflex trunk;
2 profunda femoris artery.

Fig. 27.7 There is no medial circumflex artery; the area is supplied by the obturator artery (<1%). Schematic.

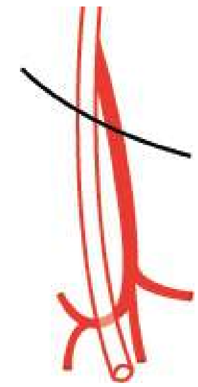

Fig. 27.8 The profunda femoris is a branch of the external iliac, sometimes together with the inferior epigastric artery (<1%). Schematic.

27.2 Course

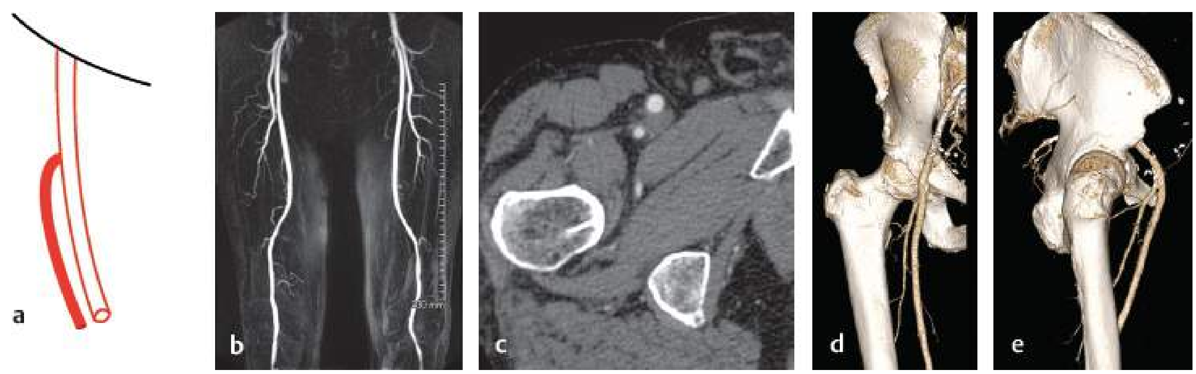

Fig. 27.9 The main stem of the profunda femoris is lateral or posterolateral to the femoral artery (48%). Schematic (**a**), coronal MIP MR (**b**), axial CT (**c**), AP CT (**d**), and right lateral 3D-VR CT (**e**).

Fig. 27.10 The main stem is posterior to the femoral artery (40%). Schematic (**a**), axial CT (**b**) and sagittal MIP CT (**c**). In the axial CT (**b**), the course shown in **Fig. 27.10a** is shown on right side, and the course shown in **Fig. 27.9a** is shown on the left side.

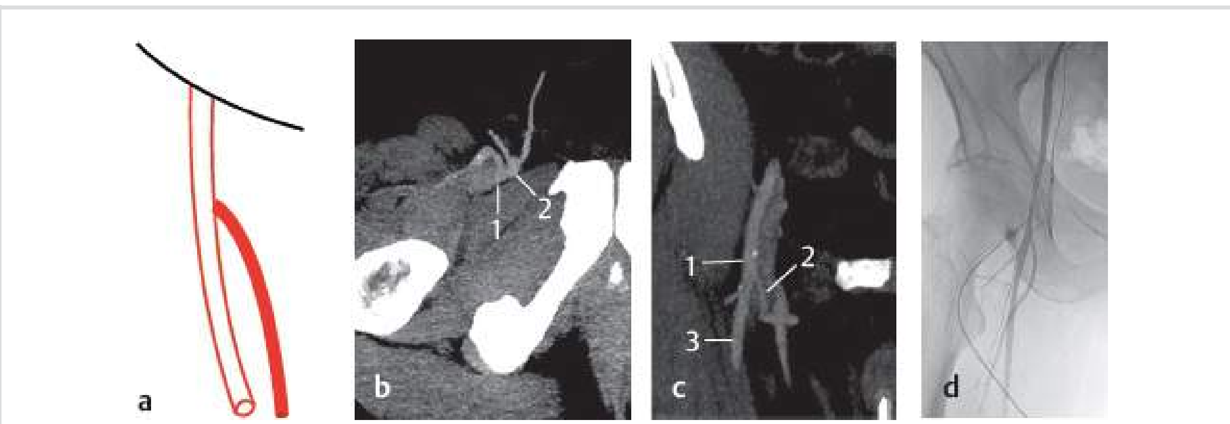

Fig. 27.11 The main stem is medial or posterior medial to the femoral artery (10%). Schematic (**a**), axial MIP CT (**b**), coronal MIP CT (**c**) and PA angiography (**d**). **1** Common femoral artery; **2** profunda femoris artery; **3** superficial femoral artery.

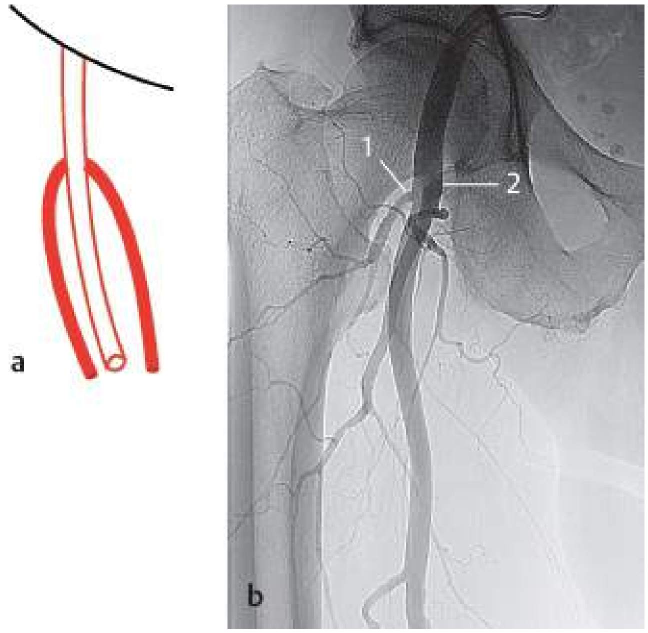

Fig. 27.12 Large branches of the profunda femoris are found medial as well as lateral to the femoral artery (2%). Schematic (**a**) and PA angiography (**b**). **1** Profunda femoris artery 1; **2** profunda femoris artery 2.

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28 Popliteal Artery

T. Rodt, M. Lee

Normally the popliteal artery divides at the upper border of the popliteal muscle. If the division is proximal to this border, it is called a high division. The anterior tibial artery runs anteriorly to the popliteal muscle and corresponds to the profound popliteal artery of most mammals. Only in primates is this vessel replaced by the more superficially positioned popliteal artery. An inter-osseous artery is very rarely found along the interosseous membrane; this artery differs from the popliteal artery.[1–5]

In addition to anomalies of the main branches of the popliteal artery,[6,7] there are many more varieties of the smaller side branches (the genicular and sural arteries). For example, common origins of the superior medial genicular and the descending genicular arteries as well as the superior lateral and the median genicular arteries are frequent. Both upper and lower arteries of the knee joint only rarely form trunks. The origin of the genicular arteries from the sural arteries has been described.

28.1 Branching of the Popliteal Artery at the Lower Border of the Popliteal Muscle (95%)

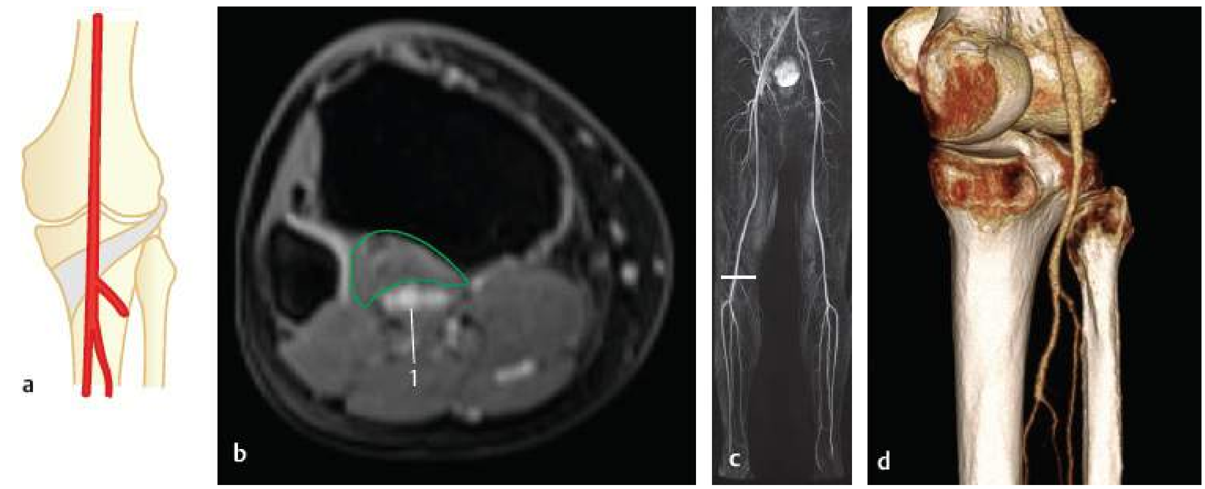

Fig. 28.1 The “normal” situation as described in text books (90%). Schematic (**a**), axial MR (**b**), coronal MRA (**c**) and posteromedial 3D-VR CT (**d**). The localization of the axial MR slice (**b**) is marked by the horizontal line in the coronal MRA (**c**). **1** Popliteal artery. The popliteus muscle is encircled in green.

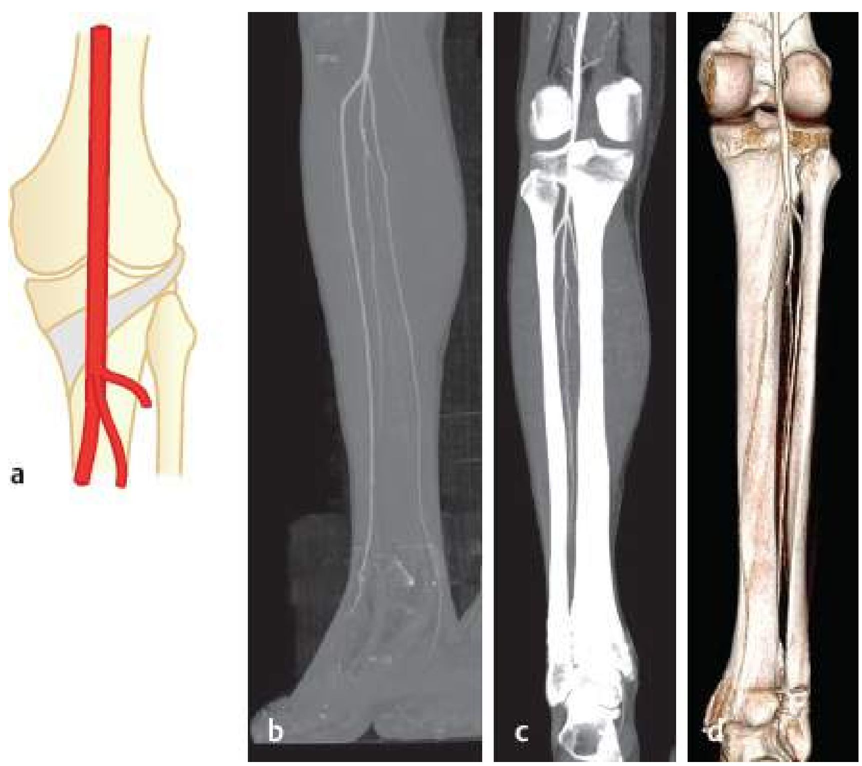

Fig. 28.2 “Trifurcation” or very short stems of the anterior,

posterior tibial, and peroneal arteries (4%). Schematic (**a**), lateral 3D-MIP CTA with bones removed (**b**), coronal MIP CTA (**c**), and posterior 3D-VR CT (**d**).

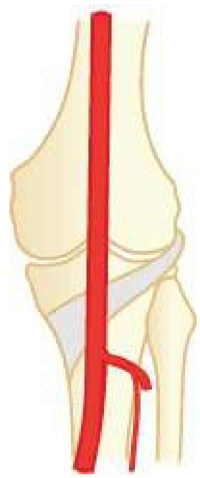

Fig. 28.3 Trunk to the anterior tibial and peroneal arteries (1%). Schematic.

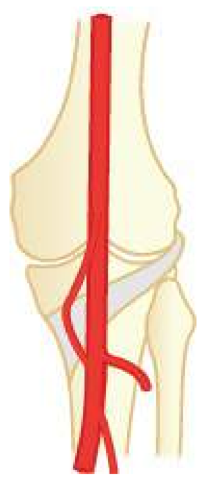

Fig. 28.4 "Island" formation of a branch (<1%). Schematic.

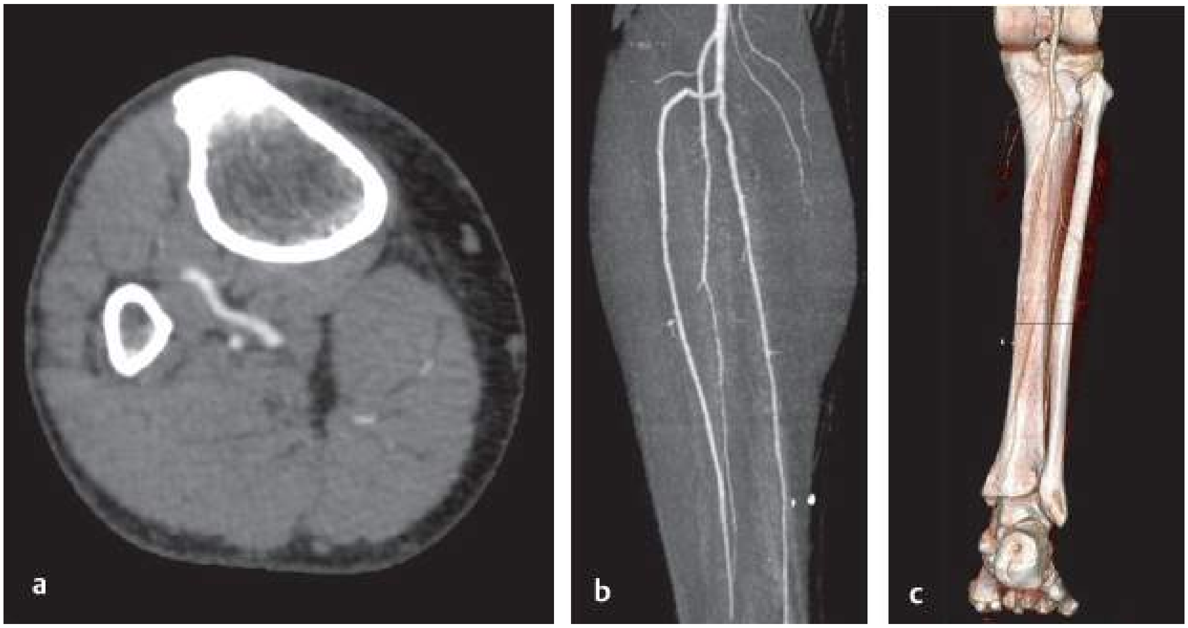

Fig. 28.5 High origin of the peroneal artery (<1%). This anomaly is not represented in the schematics above. Axial MIP CTA (**a**), lateral 3D-MIP CTA with bones removed (**b**) and posterior 3D-VR CT (**c**).

28.2 Branching of the Popliteal Artery Proximal to the Upper Margin of the Popliteal Muscle (5%)

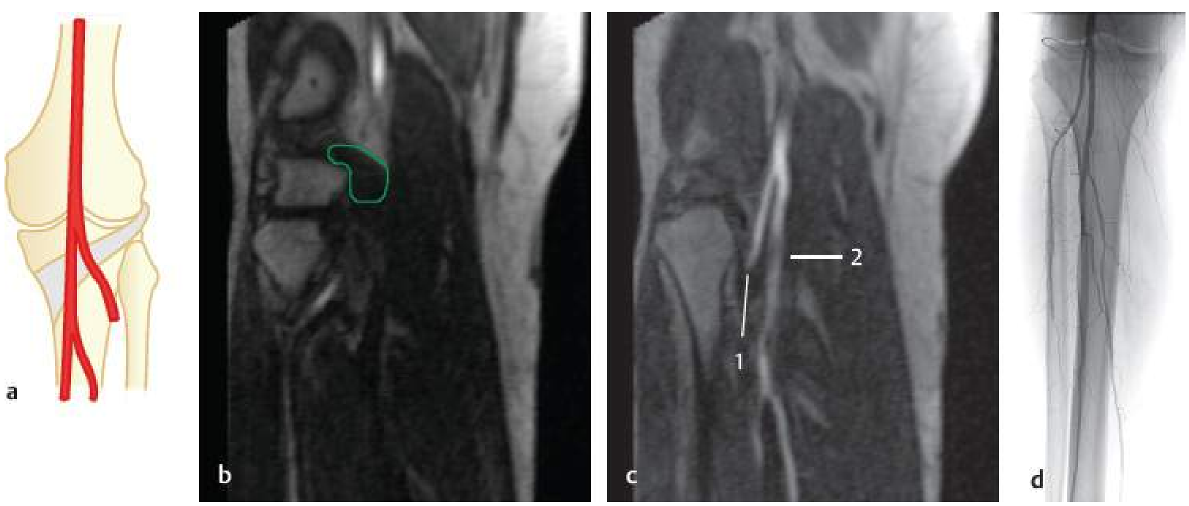

Fig. 28.6 Otherwise as normal (3%). Schematic (**a**), coronal MRA

(**b,c**), and posteroanterior angiography (**d**).
1 Anterior tibial artery; **2** tibioperoneal trunk. The popliteus muscle is encircled in green.

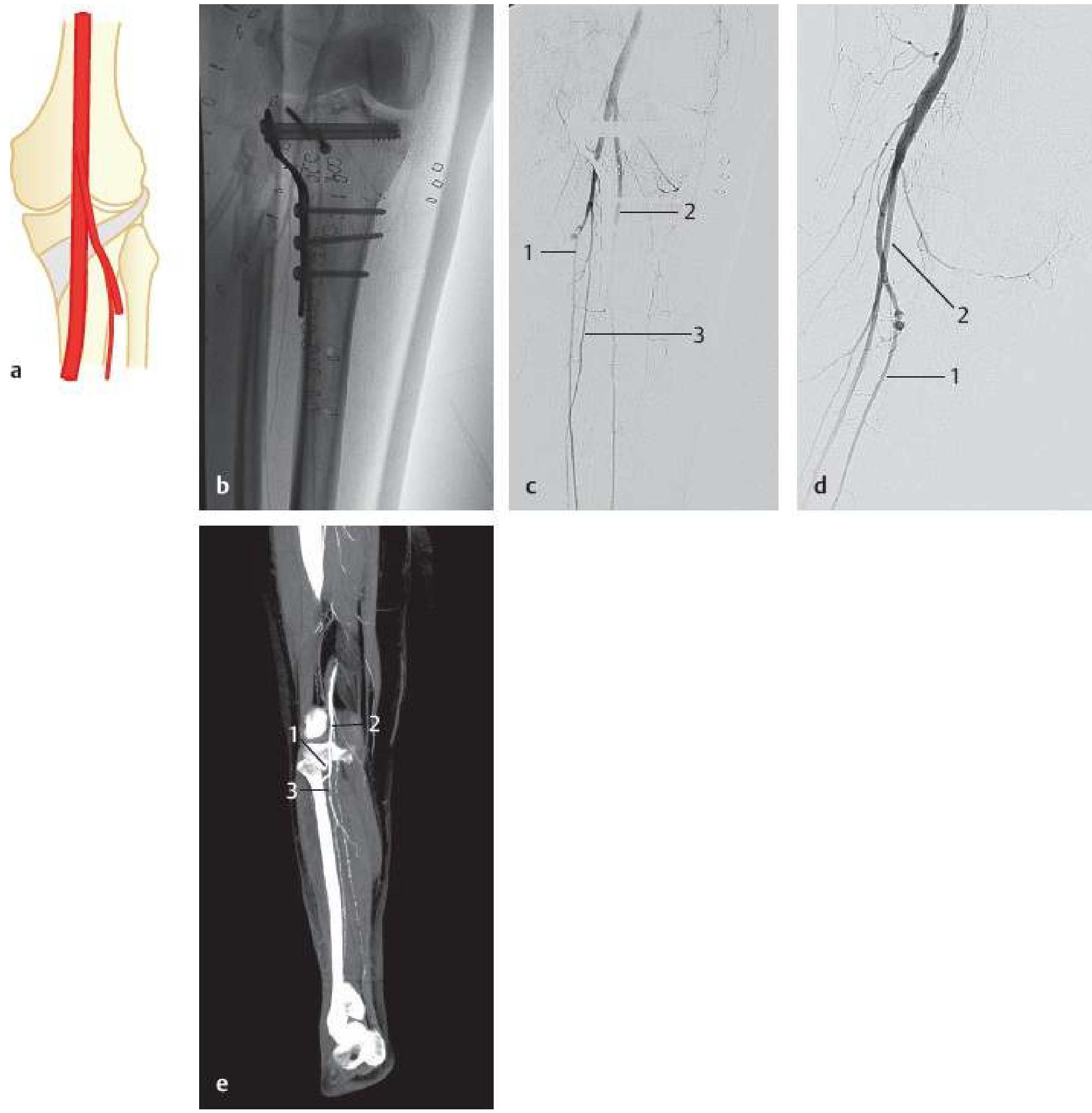

Fig. 28.7 Combined with a trunk formation (truncus peroneotibialis anterior) (1%). Schematic (**a**), posteroanterior angiography (**b**), posteroanterior and lateral DSA (**c,d**), and coronal MIP CTA in another patient (**e**). **1** Anterior tibial artery; **2** posterior tibial artery; **3** peroneal artery.

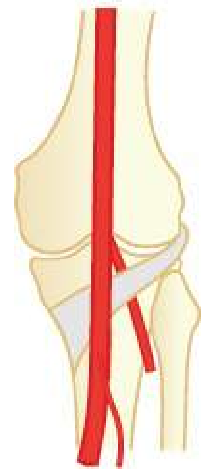

Fig. 28.8 The anterior tibial artery runs anteriorly to the popliteal muscle (1%). Schematic.

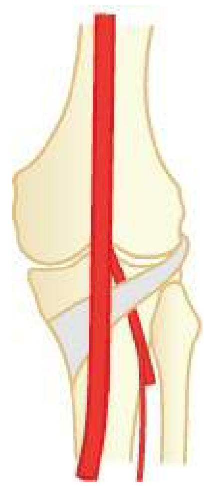

Fig. 28.9 Trunk formation: interosseous and anterior tibial artery (<0.1%). Schematic.

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29 Arteries of the Lower Leg

T. Rodt, M. Lee

The peroneal artery is the most consistently encountered artery in the lower leg. Parts of this artery stem from the original artery of the lower limb (Chapter 26). The variations in the arteries of the lower leg can be best explained by treating the peroneal artery as the main artery and defining the tibial arteries as its branches. If one of the tibial arteries is lacking or very small, the peroneal artery supplies that part of the foot. If the anterior tibial artery is absent, the perforans branch of the peroneal artery forms the dorsal artery of the foot, or if the posterior tibial artery is absent, the peroneal artery forms the plantar arteries. The peroneal artery is therefore a major contributor to the blood supply of the foot in approximately 12% of all cases. Normally, however, the peroneal artery ends in the malleolar and the calcanean areas.[1–4]

An interesting variability has been described for the nutrient artery of the tibia. In about 50% of all cases this artery branches from the posterior peroneotibial trunk, but it can also branch from the popliteal artery (at the bifurcation), the posterior or anterior tibial artery, or—rarely—the peroneal artery.[5] Depending on the origin of the nutrient artery, the nutrient foramen is most commonly found on the posteromedial surface in the upper third of the diaphysis. The location of the nutrient foramen is important in stress fractures, orthopaedic surgical procedures, and medicolegal cases.[6]

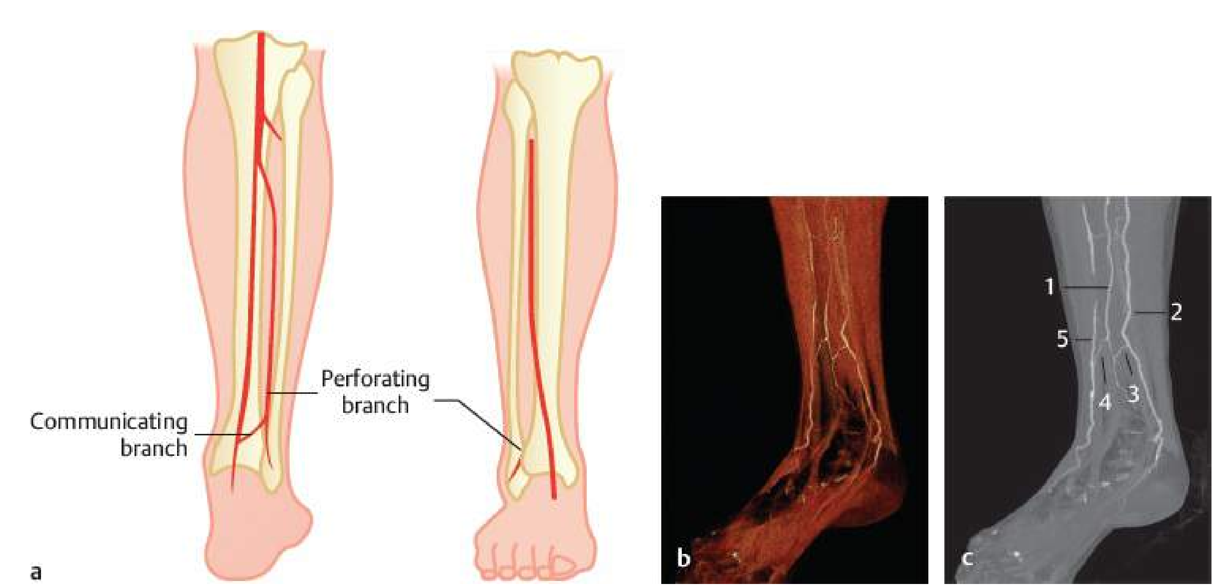

Fig. 29.1 The normal situation as shown in textbooks: the peroneal artery has a communicating branch to the posterior tibial artery and a perforating branch to the anterior tibial artery (88%). Schematic (**a**), anteromedial 3D-VR CT (**b**), and lateral MIP CTA with bones removed (**c**). **1** Peroneal artery; **2** posterior tibial artery;

3 communicating peroneal branch;

4 perforating peroneal branch;

5 anterior tibial artery.

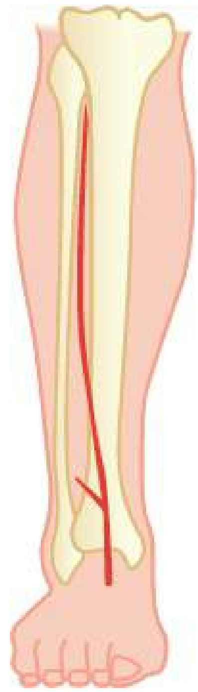

Fig. 29.2 The dorsal pedis artery originates from two roots of equal size from the peroneal and anterior tibial arteries (1%). Schematic.

Fig. 29.3 The dorsal pedis artery originates from the perforating

branch of the peroneal artery; the anterior tibial artery is absent or ends at the lower leg (6%). Schematic (**a**), posteroanterior DSA (**b,c**), and lateral DSA (**d**). **1** Peroneal artery; **2** posterior tibial artery; **3** perforating peroneal branch.

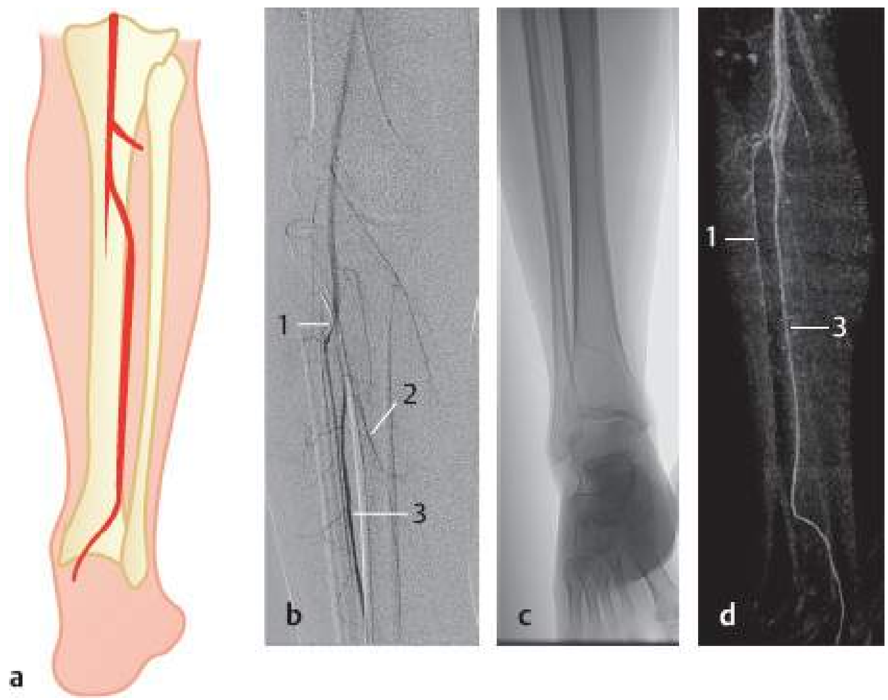

Fig. 29.4 The posterior tibial artery is absent or ends at the lower leg; the plantar arteries branch from the peroneal artery (5%). Schematic (**a**), posteroanterior DSA (**b**), posteroanterior angiography (**c**), and anterior MIP CTA with bone removal (**d**). **1** Anterior tibial artery; **2** posterior tibial artery; **3** peroneal artery.

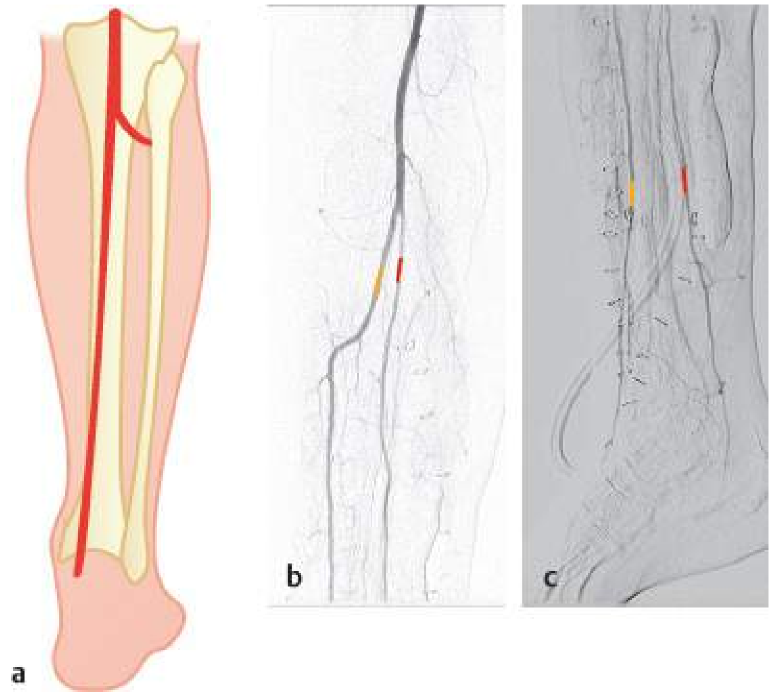

Fig. 29.5 The peroneal artery is absent (<0.1%). Schematic (**a**), posteroanterior DSA (**b**), and lateral DSA (**c**). Red lines, posterior tibial artery; orange lines, anterior tibial artery.

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30 Dorsal Arteries of the Foot

T. Rodt, M. Lee

The anterior tibial artery ends as the dorsal artery of the foot, which branches into the lateral tarsal artery and the medial tarsal arteries, and ends as the arcuate artery. This forms the dorsal metatarsal arteries, which continue as the dorsal digital arteries. In the first interosseous space, the prominent deep plantar branch is connected with the plantar arch. The other dorsal metatarsal arteries are also connected with the plantar arteries. These perforating branches can replace the dorsal metatarsal arteries.

30.1 Origin of the Arteries on the Dorsal Side of the Foot

The great variety of combinations of a more dorsal (D) or plantar (P) origin of the arteries on the dorsal side of the foot is shown. The figures do not include all the possibilities, but those omitted account for only 3 to 4% of all cases.[1–5]

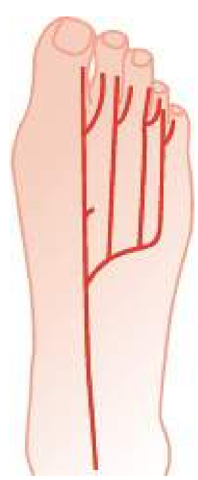

Fig. 30.1 DDDD “normal” (20%). Schematic.

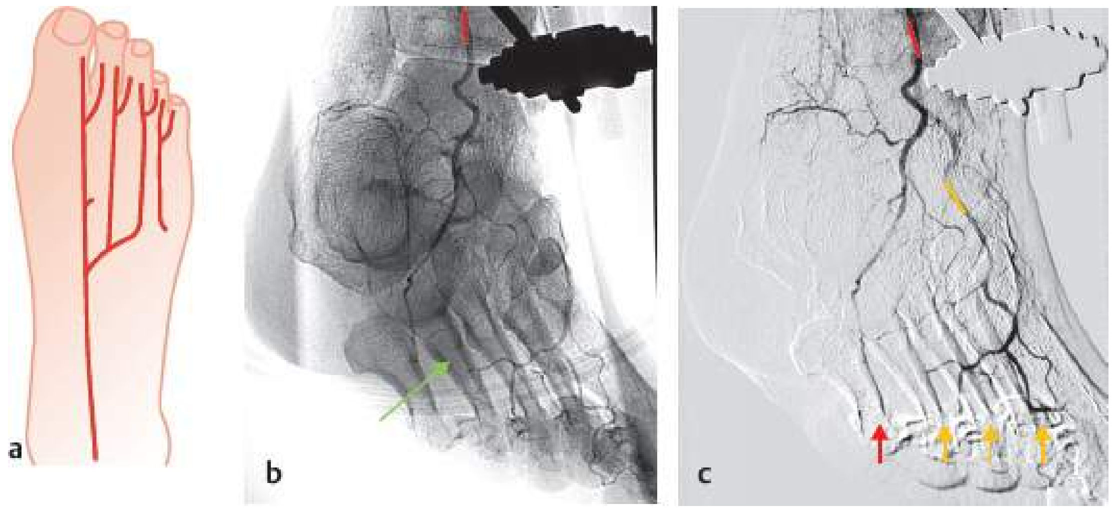

Fig. 30.2 DDDP (6%). Schematic (**a**), lateral oblique angiography (**b**), and DSA (**c**). Dorsal supply by anterior tibial artery (yellow marks), plantar supply (red arrow) by posterior tibial artery (red lines) and communicating branch (green arrow).

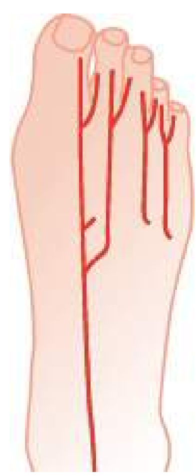

Fig. 30.3 DDPP (5%). Schematic.

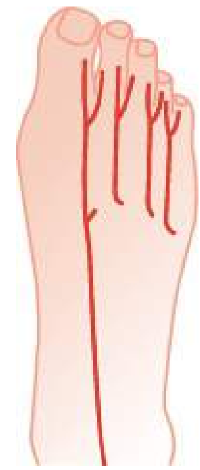

Fig. 30.4 DPPP (40%). Schematic.

Fig. 30.5 PPPP (10%). Schematic (**a**), lateral and plantodorsal DSA (**b,c**). Dorsal supply by anterior tibial artery (yellow lines), plantar supply (red arrows) by posterior tibial artery (red lines).

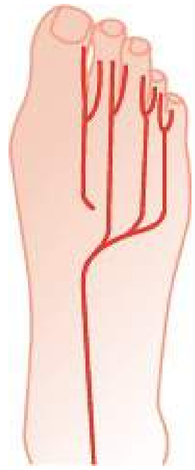

Fig. 30.6 PDDD (5%). Schematic.

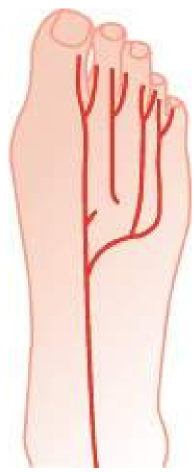

Fig. 30.7 DPDD (4%). Schematic.

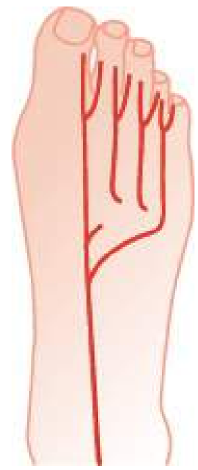

Fig. 30.8 DPPD (3%). Schematic.

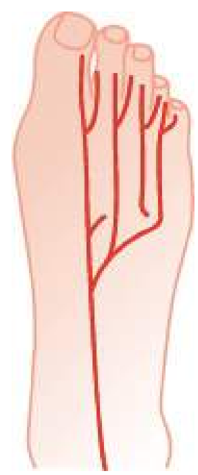

Fig. 30.9 DDPD (2%). Schematic.

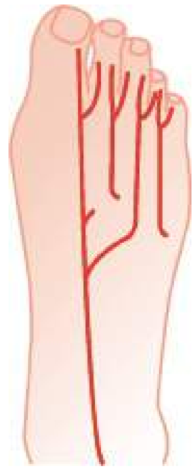

Fig. 30.10 DPDP (2%). Schematic.

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31 Plantar Arch

T. Rodt, M. Lee

The plantar arch is formed by the lateral plantar artery and the deep plantar branch of the dorsalis pedis artery. In only 1% of all cases (**Fig. 31.8**) is there no connection between these two arteries. Normally, one artery is obviously the feeding vessel, and the areas supplied by the plantar (P) or dorsal (D) arteries can be distinguished. The plantar arch is comparable to the deep palmar arch, in which the major supply also comes from the dorsal side (radial artery). A superficial arch as occurs in the palm is rarely found in the planta pedis: a major superficial plantar arch occurs in approximately 2% of all and small anastomoses in approximately 25% of all cases.[1–4]

31.1 Origin of the Plantar Metatarsal Arteries

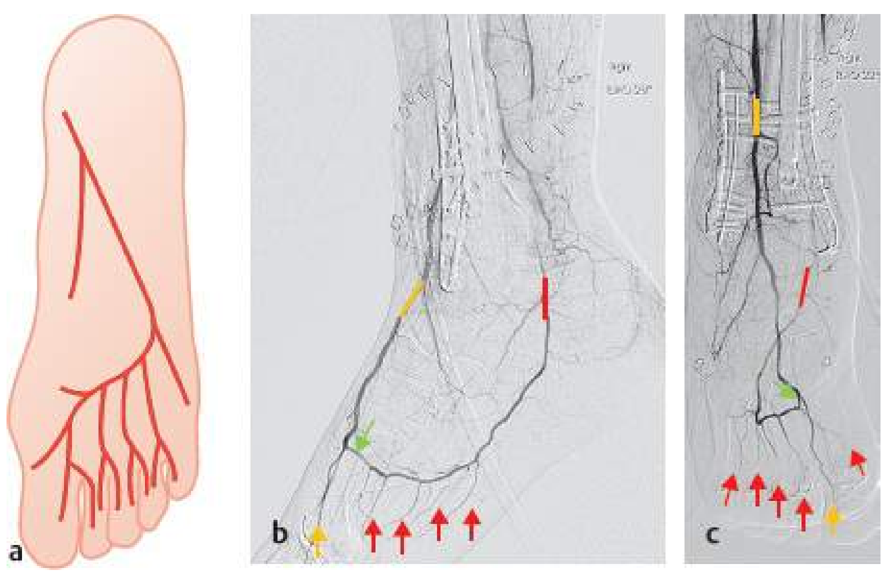

Fig. 31.1 All four plantar metatarsal and common digital arteries,

respectively, are derived from the lateral plantar artery (7%). Schematic (**a**), and lateral and plantodorsal DSA (**b,c**). Supply by anterior tibial artery via dorsalis pedis artery (yellow marks), plantar supply (red arrows) by posterior tibial artery (red lines) and communicating branch (green arrow).

Fig. 31.2 The first plantar metatarsal artery derives from the deep plantar branch (6%). Schematic (**a**), lateral and plantodorsal DSA (**b,c**). Supply by anterior tibial artery via dorsalis pedis artery (yellow marks), plantar supply by posterior tibial artery (red marks) and communicating branch (green arrow).

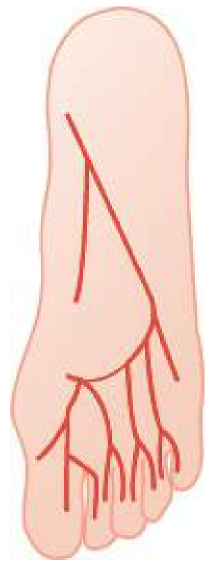

Fig. 31.3 The first and second plantar metatarsal arteries derive from the deep plantar branch (13%). Schematic.

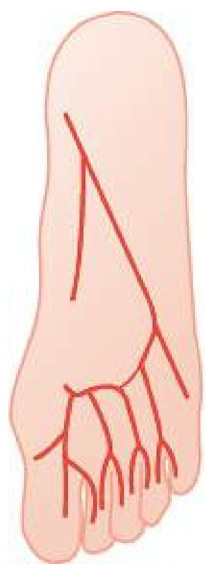

Fig. 31.4 The plantar metatarsal arteries I–III derive from the deep plantar branch (19%). Schematic.

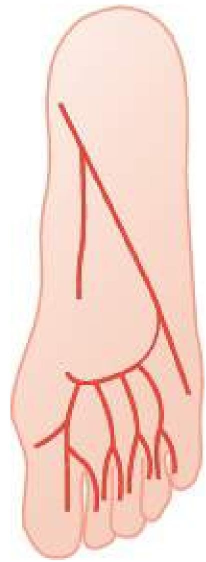

Fig. 31.5 All four plantar metatarsal arteries derive from the deep plantar branch (27%). Schematic.

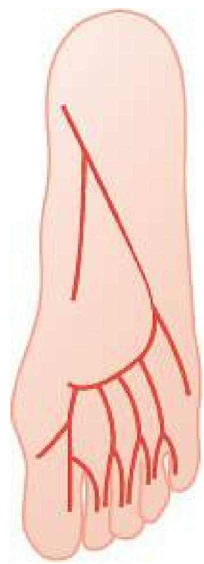

Fig. 31.6 The deep branch also reaches the lateral part of the foot (26%). Schematic.

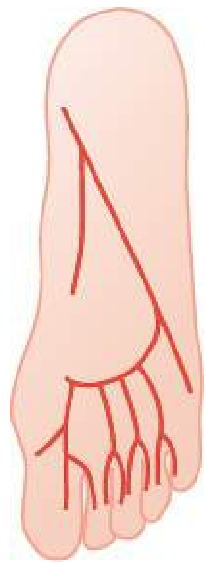

Fig. 31.7 In all areas an equally strong plantar arch without an obvious boundary between the areas supplied by the lateral plantar artery and the deep plantar branch (1%). Schematic.

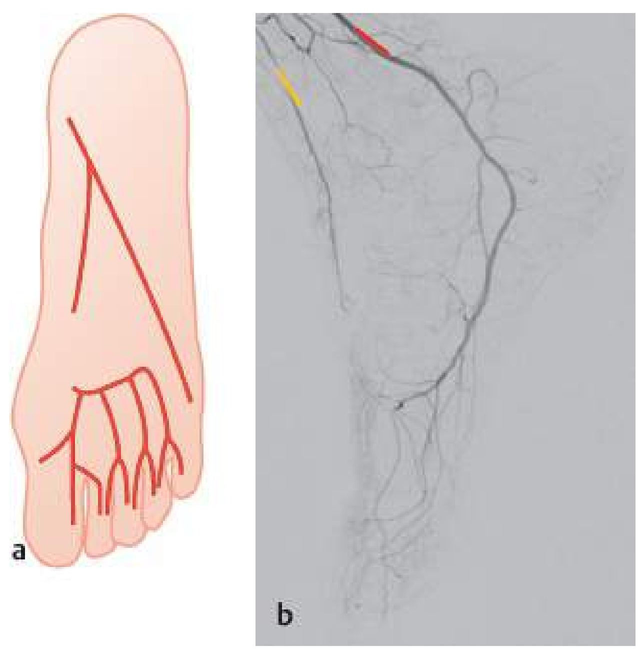

Fig. 31.8 The plantar arch is not closed (1%). Schematic (**a**) and lateral DSA (**b**). Supply by anterior tibial artery via dorsalis pedis artery (yellow mark) and plantar supply by posterior tibial artery (red mark). No communicating branch is seen; in this case, all the metatarsal

arteries originate from the lateral plantar artery.

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Part IV

Upper Limbs

32 Axillary Artery

B. Meyer, L. Sonnow

Enormous differences exist in the varieties of the axillary artery. Racial differences seem to play a role, but more important are the variations in the trunks' names. The percentages given should be taken as rough estimates. The variations shown in Section 32.2 have an overall frequency of approximately 50%, which is lower than the sum of the subtypes shown in **Fig. 32.2**, **Fig. 32.3**, **Fig 32.4**, and **Fig. 32.5** because these subtypes may occur in combination (**Fig. 32.6**). More exact data are not available.[1–15]

32.1 Normal Type as Shown in Textbooks (<10%)

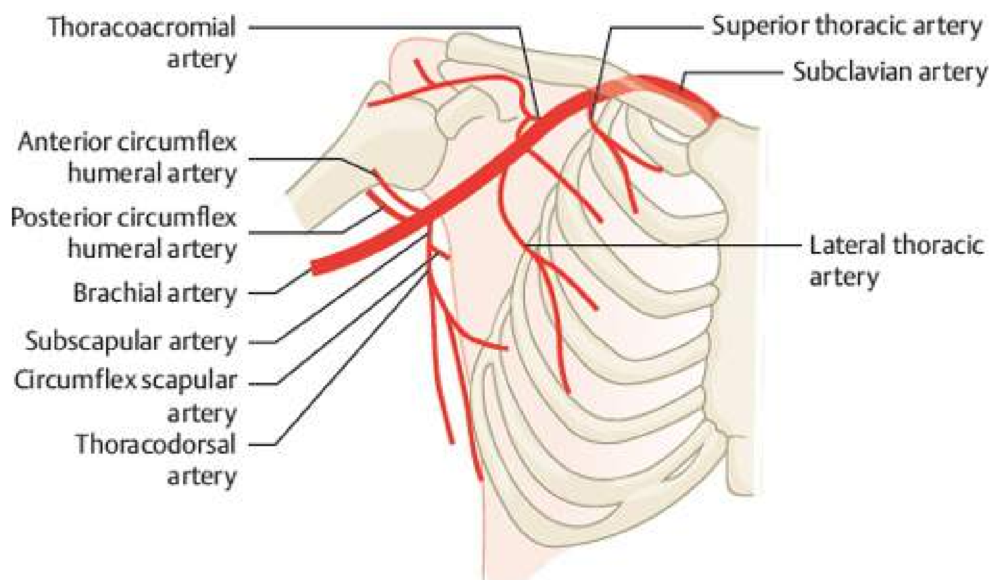


Fig. 32.1 Normal type as shown in textbooks (<10%). Schematic.

32.2 Trunk Formation of Some Branches (50%)

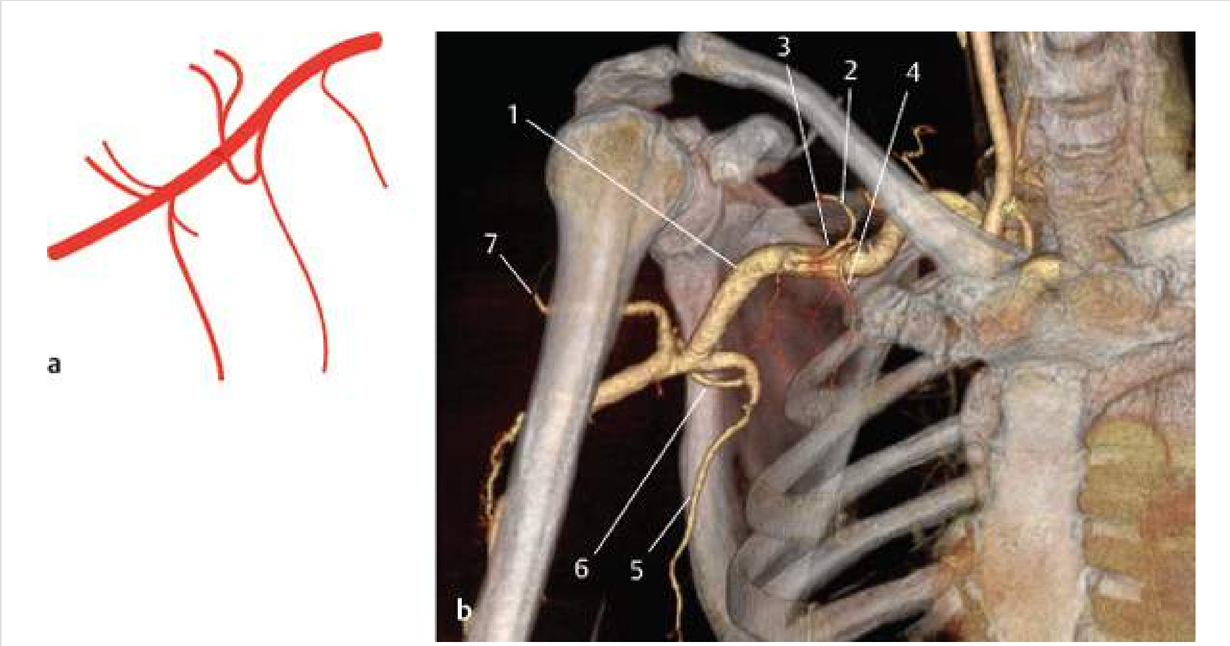


Fig. 32.2 The lateral thoracic artery forms a trunk with the thoracoacromial artery (~10%). Schematic (**a**) and VR CTA (**b**). **1** Axillary artery; **2** thoracoacromial artery; **3** common trunk; **4** lateral thoracic artery; **5** thoracodorsal artery; **6** circumflex scapular artery; **7** posterior circumflex humeral artery.

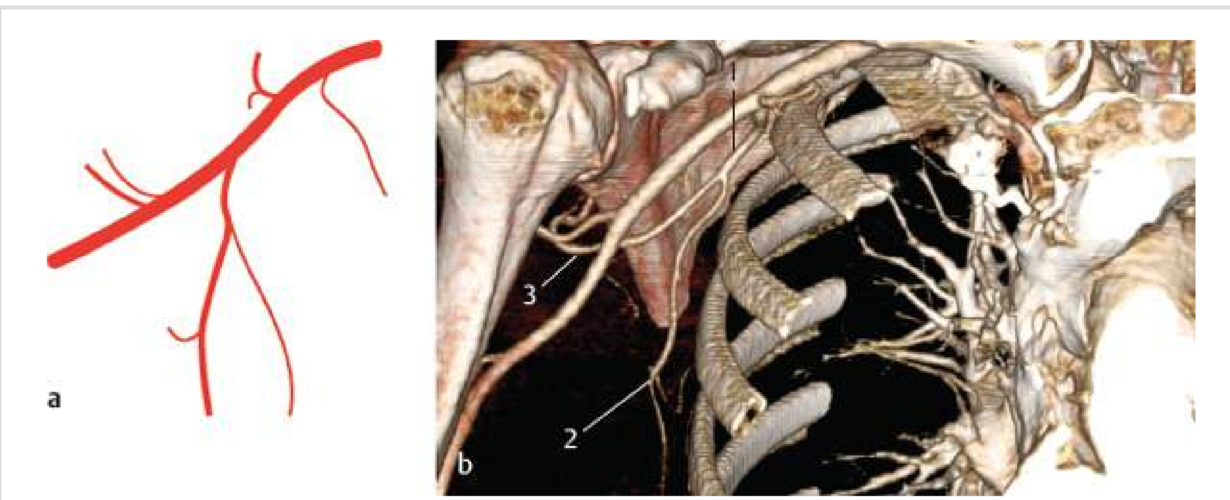


Fig. 32.3 The lateral thoracic artery originates with the subscapular artery (~10%). Schematic (**a**) and VR CTA (**b**). **1**

Subscapular artery; **2** lateral thoracic artery; **3** circumflex scapular artery.

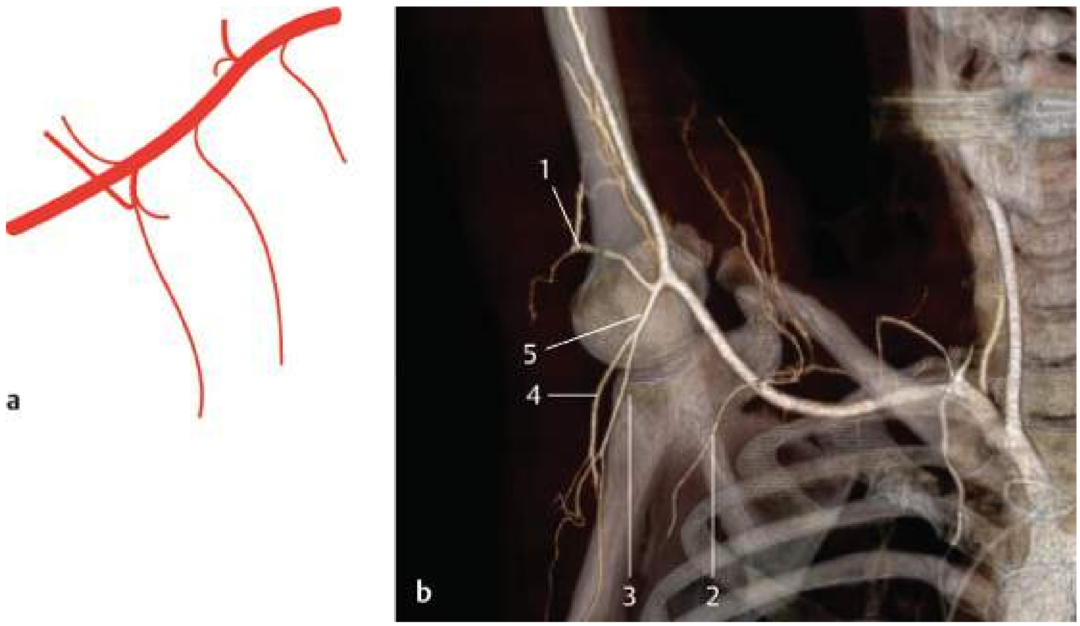


Fig. 32.4 The subscapular artery forms a trunk with the posterior circumflex artery of the humerus (~20%). Schematic (**a**) and VR CTA (**b**). **1** Posterior circumflex humeral artery; **2** lateral thoracic artery; **3** thoracodorsal artery; **4** circumflex scapular artery; **5** subscapular artery.

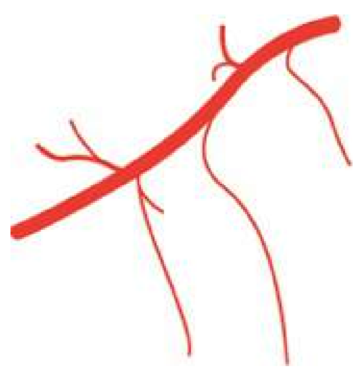


Fig. 32.5 Both circumflex arteries of the humerus form a trunk (20%). Schematic.

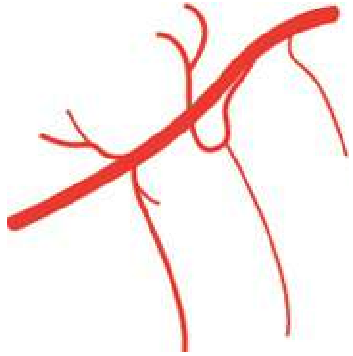


Fig. 32.6 Combination of the types shown in Fig. 32.2, Fig. 32.3, Fig. 32.4, and Fig. 32.5 (e.g., combination of **Fig. 32.2** and **Fig. 32.5**). Schematic.

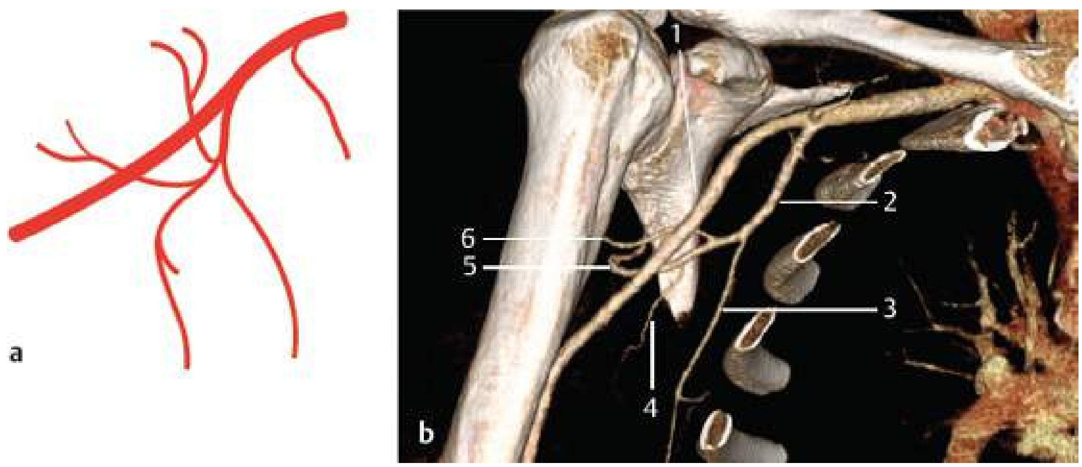


Fig. 32.7 The majority of branches originate as a common trunk from the axillary artery (2%). Schematic (**a**) and VR CTA (**b**). **1** Axillary artery; **2** common trunk; **3** lateral thoracic artery; **4** thoracodorsal artery; **5** circumflex scapular artery; **6** posterior circumflex humeral artery.

32.3 High Origin of Arteries of the Arm (22%)

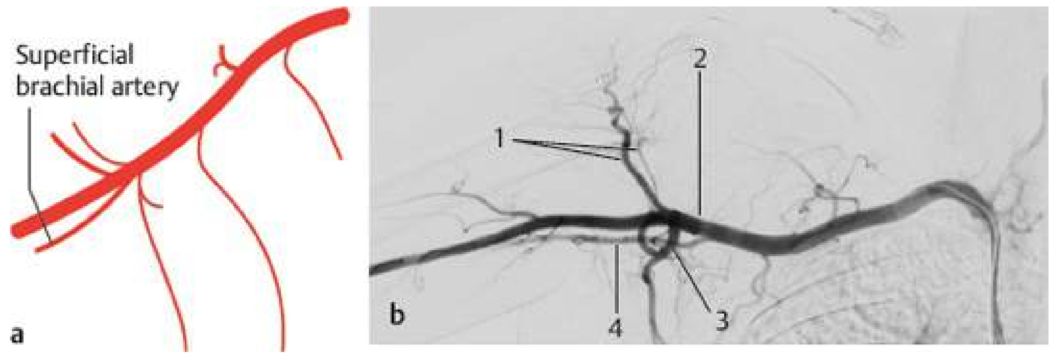


Fig. 32.8 A superficial brachial artery derives from the axillary artery (4%). Schematic (**a**) and DSA (**b**). **1** Circumflex humeral arteries; **2** axillary artery; **3** subscapular artery; **4** superficial brachial artery.

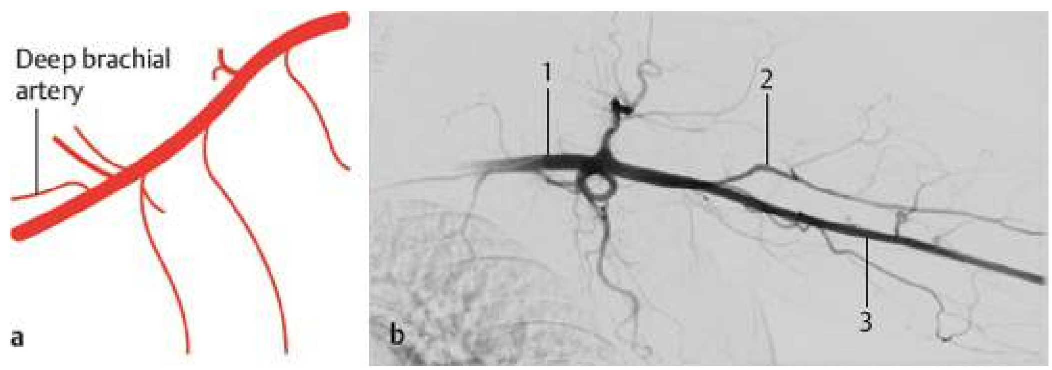
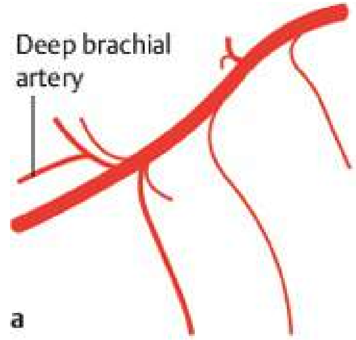


Fig. 32.9 The deep brachial artery originates from the axillary artery (13%). Schematic (**a**) and DSA (**b**). **1** Axillary artery; **2** deep brachial artery; **3** brachial artery.



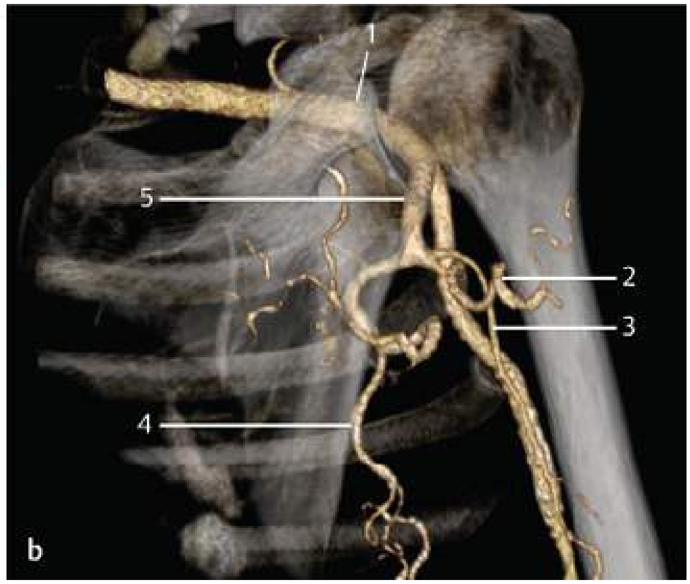


Fig. 32.10 The deep brachial artery is a branch of the posterior circumflex artery of the humerus (5%). Schematic (**a**) and VR CTA (**b**). **1** Axillary artery; **2** circumflex humeral artery; **3** deep brachial artery; **4** thoracodorsal artery; **5** common trunk.

32.4 Other Variations (21%)

Fig. 32.11 Accessory branches (e.g., accessory thoracodorsal artery[16]) to the thoracic wall (6%). Schematic.

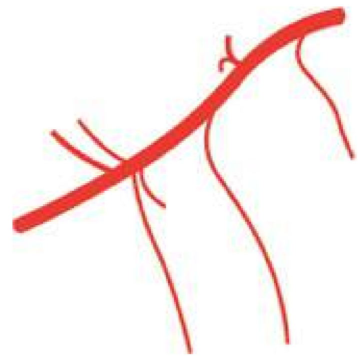


Fig. 32.12 The scapular circumflex artery and thoracodorsal arteries originate separately from the axillary artery (4%). Schematic.

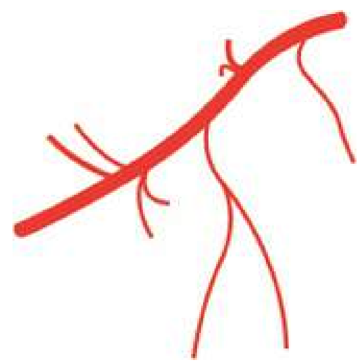


Fig. 32.13 The lateral thoracic artery is prominent, whereas the thoracodorsal artery is small (3%). Schematic.

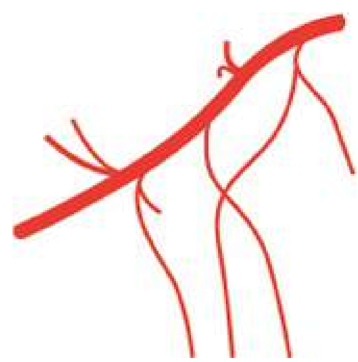


Fig. 32.14 The superior thoracic artery has a long descending branch (1%). Schematic.

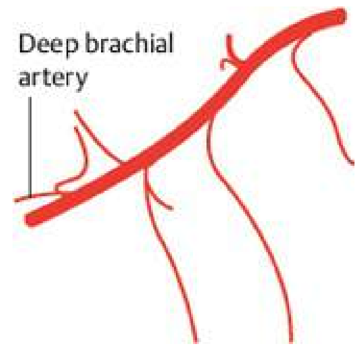


Fig. 32.15 The posterior circumflex artery of the humerus originates from the brachial or deep brachial artery (7%). Schematic.

Fig. 32.16 The suprascapular artery is a branch of the axillary artery instead of the thyrocervical trunk (<1%). Schematic.

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33 Development of the Arteries of the Arm

B. Meyer, L. Sonnow

The arteries of the arm show many rearrangements (**Fig. 33.1**), especially the arteries of the forearm, which develop like the arteries in the leg. The axial artery of the arm is the continuation of the sixth cervical segmental artery (see Chapter 2). This artery has different names: it starts as the subclavian artery, continues as the axillary artery, and is named the brachial artery after passing the posterior axillary fold. In the forearm, the continuation was originally the interosseous artery, which initially supplied the arteries of the fingers. At the next stage, the median artery, which runs with the median nerve, becomes the main artery. In lower mammals, the median artery supplies the finger arteries, and in nonmammals the interosseous artery even remains the main vessel. Only in primates does the final arrangement take place.

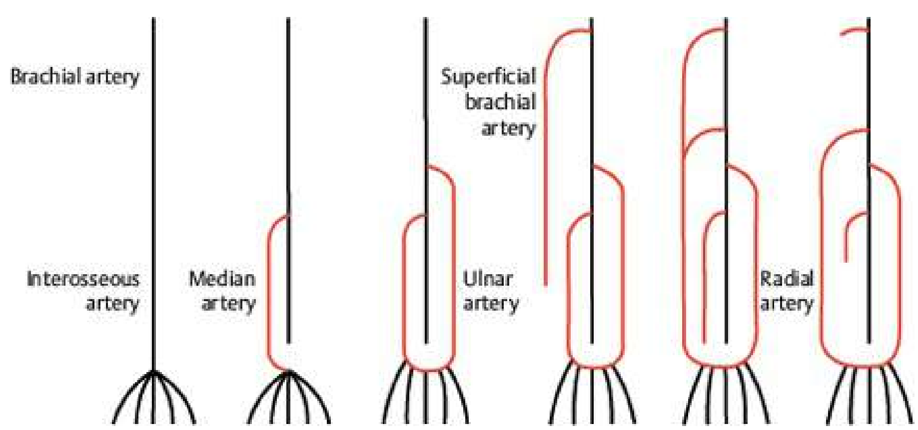

Fig. 33.1 A rough sketch of the development of the arteries of the upper limb. The original system is shown in black; arteries formed at

later stages are shown in red.

In human embryos of approximately 18 mm crown–heel length, the ulnar artery as a branch of the brachial artery forms the superficial arterial palmar arch, which supplies the arteries of the fingers. In embryos of 21-mm length, the superficial vessels widen, starting from the axillary region. This superficial brachial artery turns to the lateral side and ends on the dorsal side of the hand. This vessel also connects to the palmar arch and the median artery regresses (embryo of 23-mm length). An anastomosis between the superficial brachial and the brachial artery increases in size, while the proximal part of the superficial brachial artery normally disappears. What remains is the radial artery. This complicated development explains the many variants observed. However, since anastomoses are formed with other additional superficial arteries of the forearm (superficial antebrachial artery), the picture becomes even more confusing. **Fig. 33.2** shows the general possibilities, with the different types outlined in Chapter 34 and Chapter 35.[1–6]

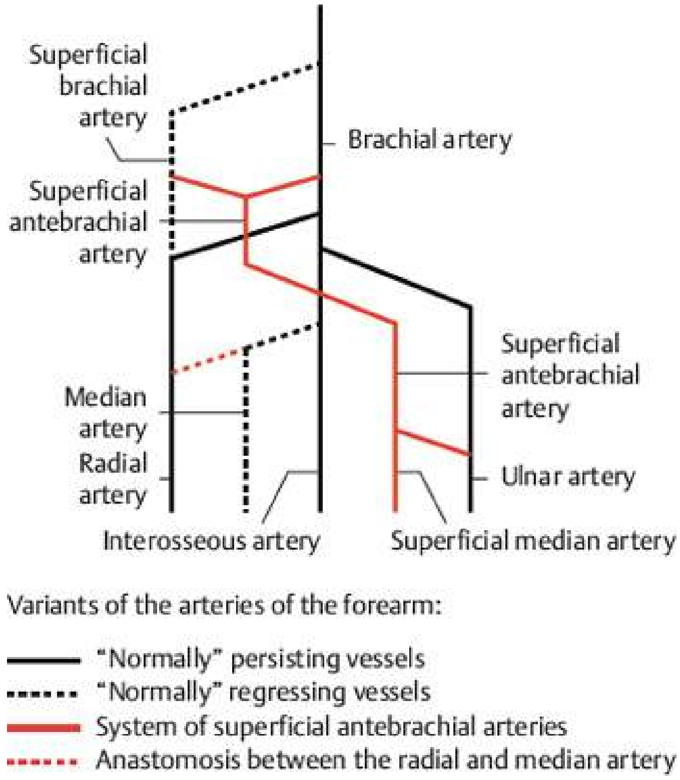

Fig. 33.2 Variants of the arteries of the forearm. Schematic. The solid black line represents "normally" persisting vessels; the dashed black line represents "normally" regressing vessels; the solid red line represents the system of superficial antebrachial arteries; and the dashed red line represents an anastomosis between the radial and median arteries.

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34 Brachial Artery and Superficial Brachial Artery

B. Meyer, L. Sonnow

The superficial brachial artery is the name of a major artery which is superficial to the median nerve on the upper arm. Such an artery can replace the normal brachial artery or occur in addition to it. When calculating the frequency, only arteries were included which reach the forearm, not minor branches such as those to the biceps muscle. The superficial brachial artery normally branches from the proximal part of the upper arm and only rarely from the distal half.[1–13]

The practical importance of this artery is that it often runs to the forearm in front of the aponeurosis of the biceps muscle and can be mistaken for a vein. An “intravenous” injection in such an artery can result in the loss of the hand or forearm. One should keep in mind that every fifth patient has a superficial artery in the cubital fossa which could be mistaken for a vein.[14–16]

34.1 Only a Brachial Artery (78%)

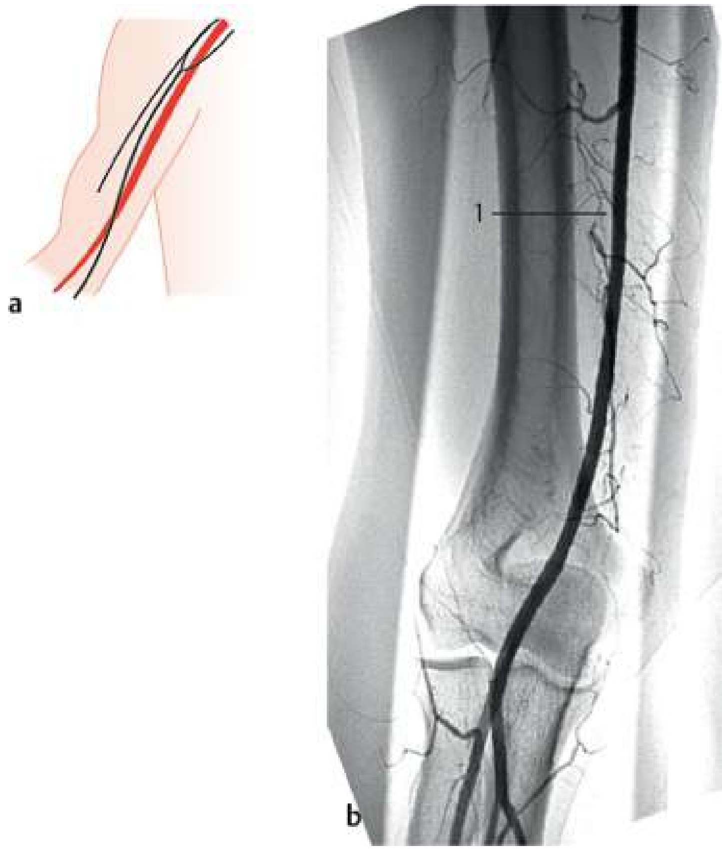

Fig. 34.1 “Normal” situation as shown in textbooks; the artery is positioned behind the median nerve, crossing beneath it at the upper arm (75%). Schematic (**a**) and unsubtracted DSA (**b**). **1** brachial artery.

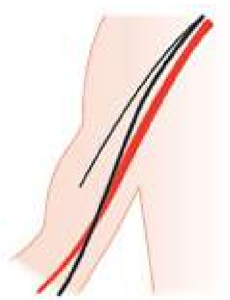

Fig. 34.2 There is no typical median nerve in the axilla; the artery crosses below the nerve as usual (3%). Schematic.

34.2 Only a Superficial Brachial Artery (9%)

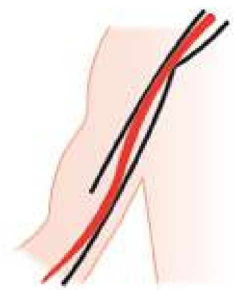

Fig. 34.3 Main artery in front of the two roots of the median nerve (2%). Schematic.

Fig. 34.4 Main artery behind the two roots of the median nerve, but crossing below it at the upper arm (5%). Schematic.

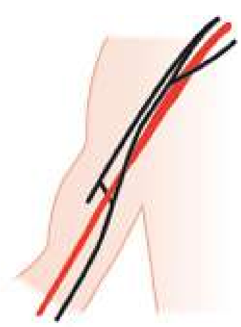

Fig. 34.5 The artery crosses beneath the median nerve on the posterior side, but over the nerve branch between the musculocutaneous and median nerve (1%). Schematic.

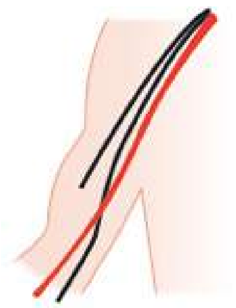

Fig. 34.6 No typical formation of the median nerve in two roots; the artery crosses over the median nerve (1%). Schematic.

34.3 Two Main Arterial Stems (13%)

Fig. 34.7 The axillary artery divides into two stems, one running behind and the other in front of the two roots of the median nerve

(4%). Schematic (**a**) and DSA from two different patients (**b,c**). **1** Superficial brachial artery; **2** posterior circumflex humeral artery; **3** brachial artery.

Fig. 34.8 The brachial artery divides into two stems, one artery running in front of the median nerve (8%). Schematic (**a**) and DSA (**b**). **1** Brachial artery; **2** superficial brachial artery.

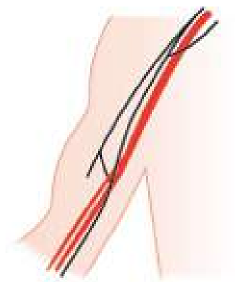

Fig. 34.9 The brachial artery divides into two stems; one artery crosses over the nerve anastomosis between the musculocutaneous and median nerve (<1%). Schematic.

Fig. 34.10 High division of a superficial brachial artery (both running superficially) (1%). Schematic.

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35 Arteries of the Forearm

B. Meyer, L. Sonnow

Fig. 35.1 summarizes all cases in which the arteries of the forearm follow a “normal” course, leaving the origin of these arteries out of consideration. **Fig. 35.2**, **Fig. 35.3**, **Fig. 35.4**, and **Fig. 35.5** demonstrate the embryological basis for the more important variations. The origin of an ulnar artery as a branch of the superficial brachial artery running parallel to a brachial artery (Section 34.3) has not been described. The superficial arteries of the forearm usually branch from a superficial brachial artery, which runs parallel to the brachial artery (Section 34.3). Sometimes the superficial arteries of the forearm are branches of the brachial artery.[1–9]

35.1 “Normal” Arterial Pattern of the Forearm (Radial, Ulnar, and Interosseous Artery) (84%)

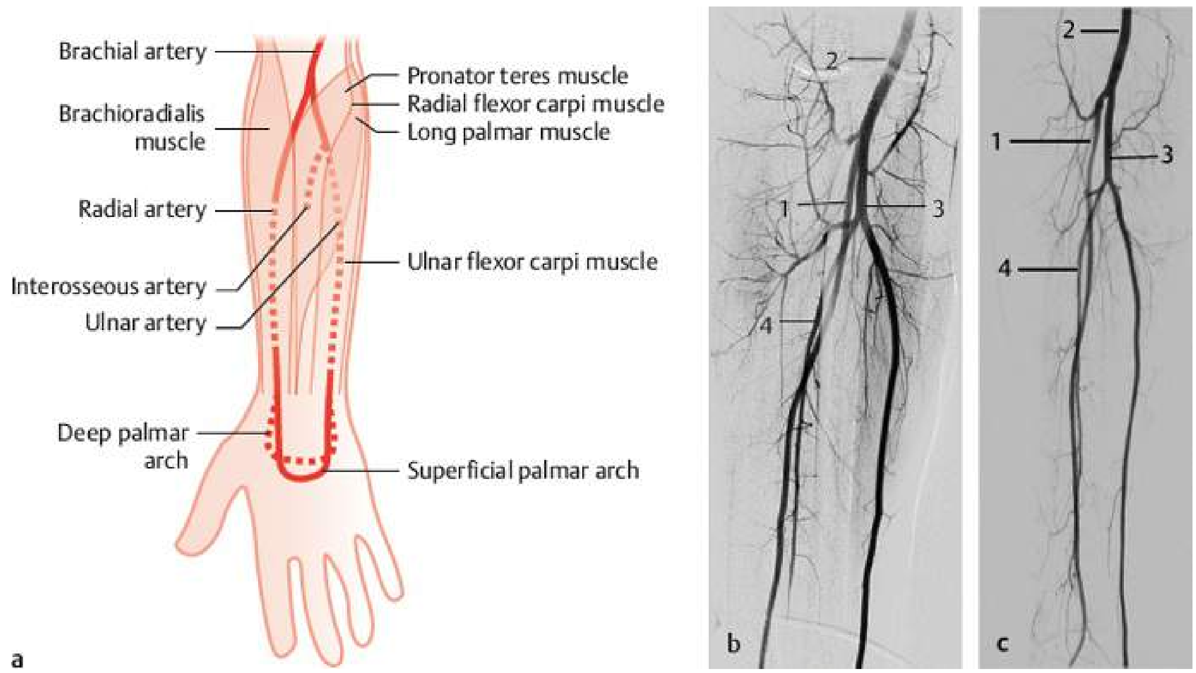

Fig. 35.1 Normal arterial pattern of the forearm. Schematic (**a**) and DSA images of the forearm from two different patients (**b,c**). **1** Radial artery; **2** brachial artery; **3** ulnar artery; **4** interosseous artery.

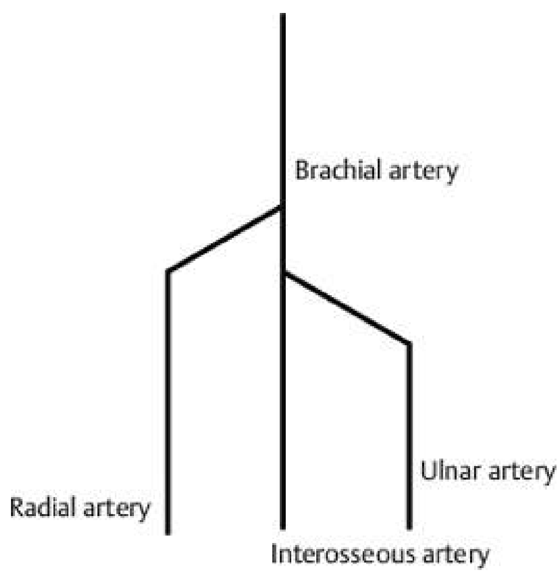

Fig. 35.2 All arteries of the forearm branch from the branchial artery (70%). See also Section 34.1. Schematic.

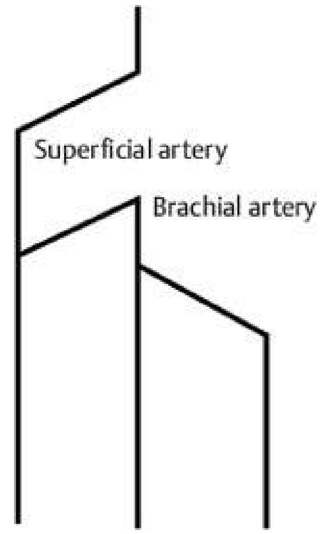

Fig. 35.3 All arteries of the forearm are branches of a superficial branchial artery (6%). Schematic.

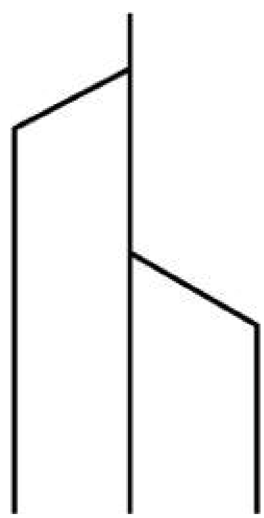

Fig. 35.4 The radial artery originates from the superficial branchial artery, and the ulnar and interosseous artery from the branchial artery (5%). Schematic.

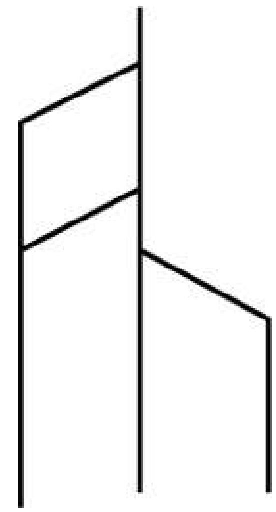

Fig. 35.5 Same as Fig. 35.3, but with a large anastomosis between the brachial and radial arteries in the cubital region (3%). Schematic.

35.2 Superficial Arteries of the Forearm (Superficial Antebrachial Artery) (8%)

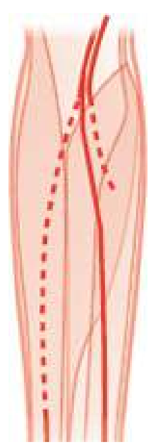

Fig. 35.6 Superficial ulnar artery replaces the ulnar artery (3%). Schematic.

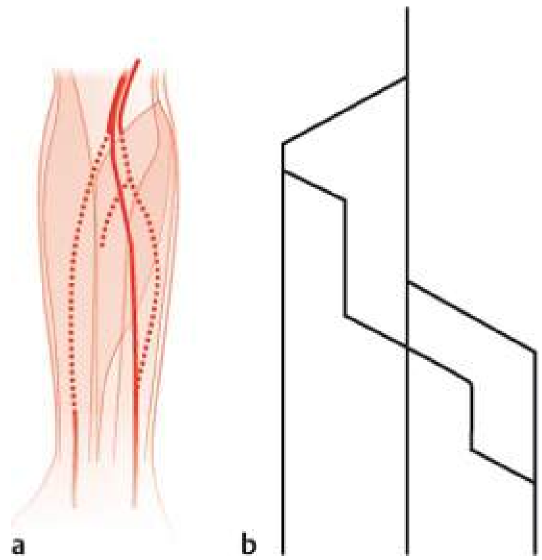

Fig. 35.7 Superficial ulnar artery joins the ulnar artery (<1%). Schematic (**a**) and sketch of the basic course of the arteries (**b**).

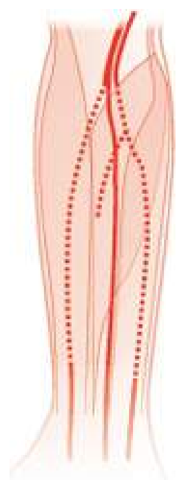

Fig. 35.8 Superficial median artery (2%). Schematic.

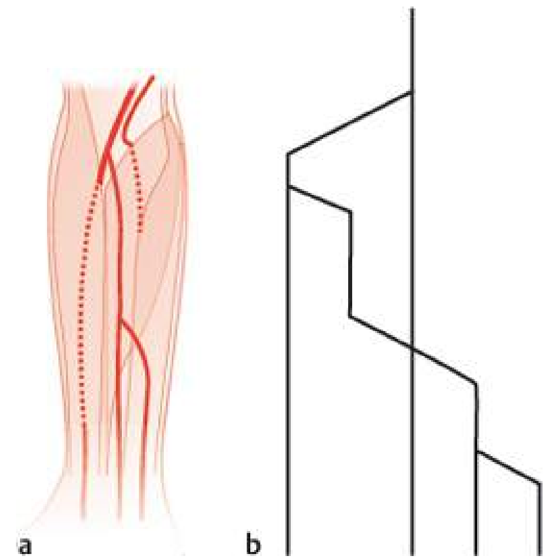

Fig. 35.9 Superficial medioulnar artery (<1%). Schematic (**a**) and sketch of the basic course of the arteries (**b**).

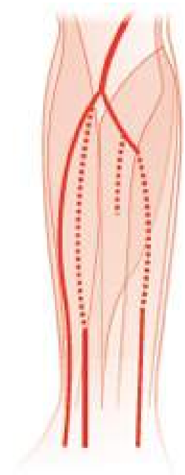

Fig. 35.10 Superficial radial artery in addition to a normal radial artery (1%). Schematic.

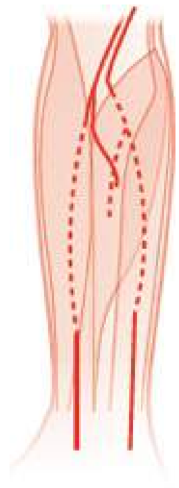

Fig. 35.11 The superficial antebrachial artery ends at the proximal part of the forearm (1%). Schematic.

35.3 Median Artery (8%)

The median artery is present in early embryonic development, but regresses as early as the second embryonic month (see Chapter 33). This regression can occur much later, resulting in the obliteration of parts of the median artery in adults. Normally, the median artery runs parallel to the median nerve, but superficial median arteries have also been described (**Fig. 34.5** and **Fig. 34.6**), which pass the flexor muscles obliquely and reach the median nerve further distally.[1,5]

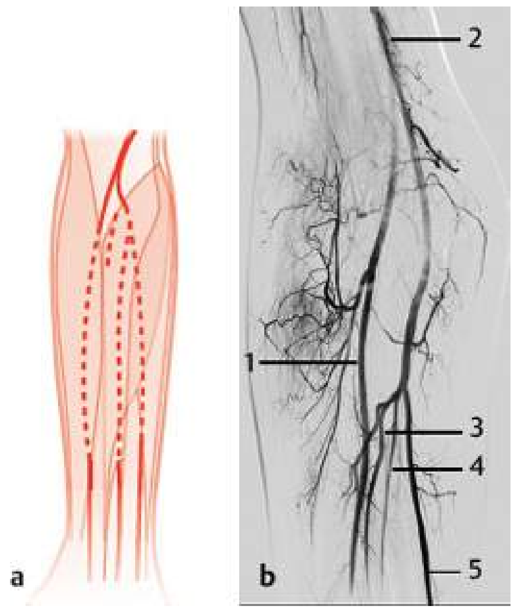

Fig. 35.12 Median artery. Schematic (**a**) and DSA (**b**) of the forearm demonstrating a persistent median artery; common origin of median and interosseous artery. **1** Radial artery; **2** brachial artery; **3** interosseous artery; **4** median artery; **5** ulnar artery.

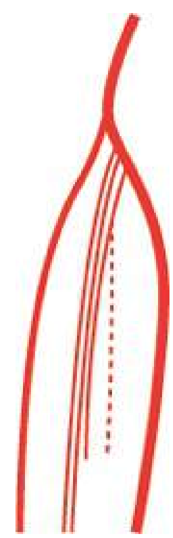

Fig. 35.13 Origin from the ulnar artery proximal to or with the common interosseous artery (2%). Schematic.

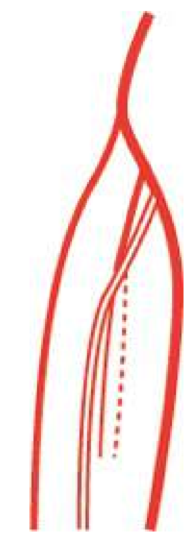

Fig. 35.14 Origin from the ulnar artery distal to the common inter-osseous artery (3%). Schematic.

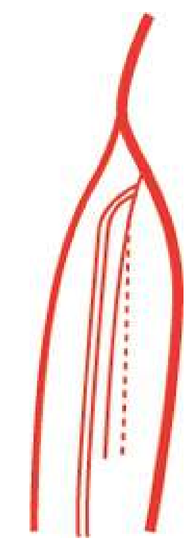

Fig. 35.15 Origin from the common interosseous artery (2%). Schematic.

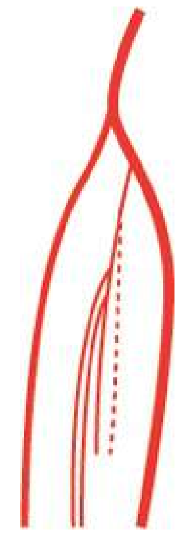

Fig. 35.16 Origin from the anterior interosseous artery (1%). Schematic.

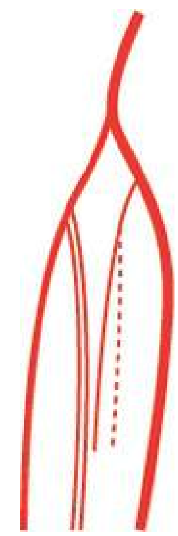

Fig. 35.17 Origin from the radial artery (0.1%). Schematic.

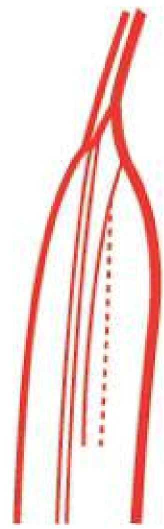

Fig. 35.18 Origin from an anastomosis between the radial and brachial artery (0.1%). Schematic.

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36 Superficial Palmar Arch

B. Meyer, L. Sonnow

It is often difficult to distinguish between the types of the superficial palmar arch shown in Sections 36.1 and 36.2: the anastomosis can be so variable in size that the relative contribution to the supply of the hand is difficult to assess.

The number of types of anomalies actually observed is even larger than shown in these figures, since all four common palmar digital arteries do not originate from the superficial palmar arch (Chapter 37). Quite often, the first common palmar digital artery is absent, which normally supplies the ulnar side of the thumb and the radial side of the index finger. In such cases, the princeps pollicis artery is the only artery for that region. Because of the frequent absence of the first common palmar digital artery, only the next artery is sometimes designated the common palmar digital artery. This is called II in our figures because it is found in the second interosseous space.

In these figures, no differentiation has been made as to whether the feeding median artery is a "normal" median artery or a superficial median artery in the forearm.[1–16]

36.1 Closed Arch (42%)

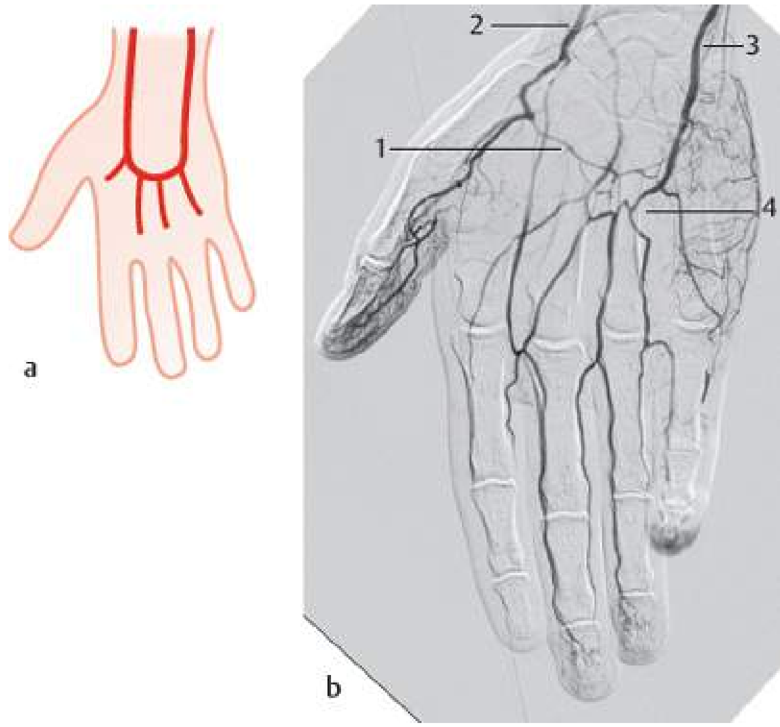

Fig. 36.1 “Normal” situation as described in textbooks (radioulnar type) (35%). Schematic (**a**) and DSA (**b**). **1** Deep palmar arch; **2** radial artery; **3** ulnar artery; **4** superficial palmar arch.

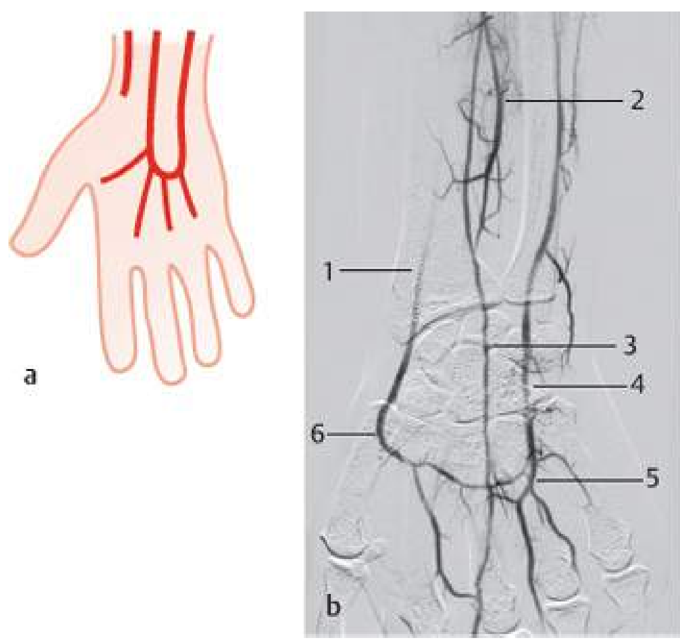

Fig. 36.2 Medianoulnar type (4%). Schematic (**a**) and DSA (**b**). **1**

Radial artery; **2** interosseous artery; **3** median artery; **4** ulnar artery; **5** superficial palmar arch; **6** deep palmar arch.

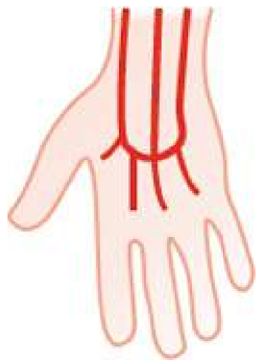

Fig. 36.3 Radiomedianoulnar type (1%). Schematic.

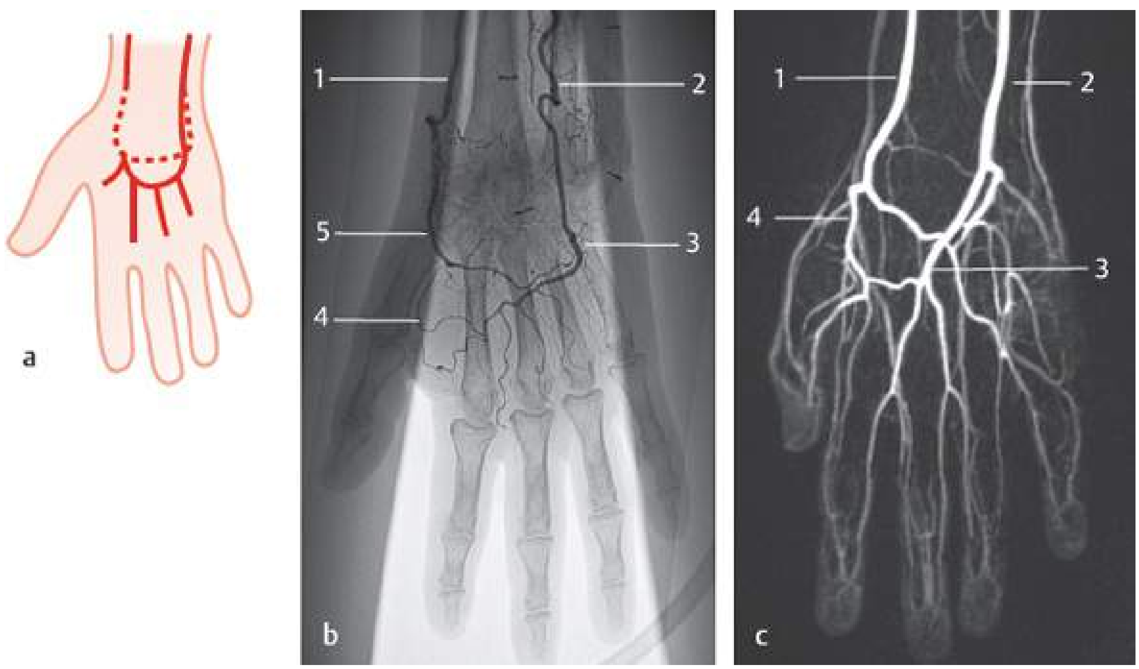

Fig. 36.4 Profundoulnar type (the branch of the radial artery comes from the posterior side or from the deep palmar arch) (2%). Schematic (**a**), unsubtracted DSA (branch from the deep palmar arch) (**b**), and contrast-enhanced MR angiography, MIP (**c**). **1** Radial artery; **2** ulnar artery; **3** superficial palmar arch; **4** branch from the deep palmar arch; **5** incomplete deep palmar arch.

36.2 Incomplete Arch (58%)

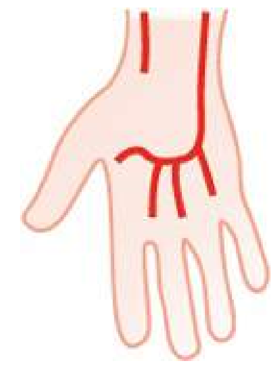

Fig. 36.5 All four common palmar digital arteries from the ulnar artery (37%). Schematic.

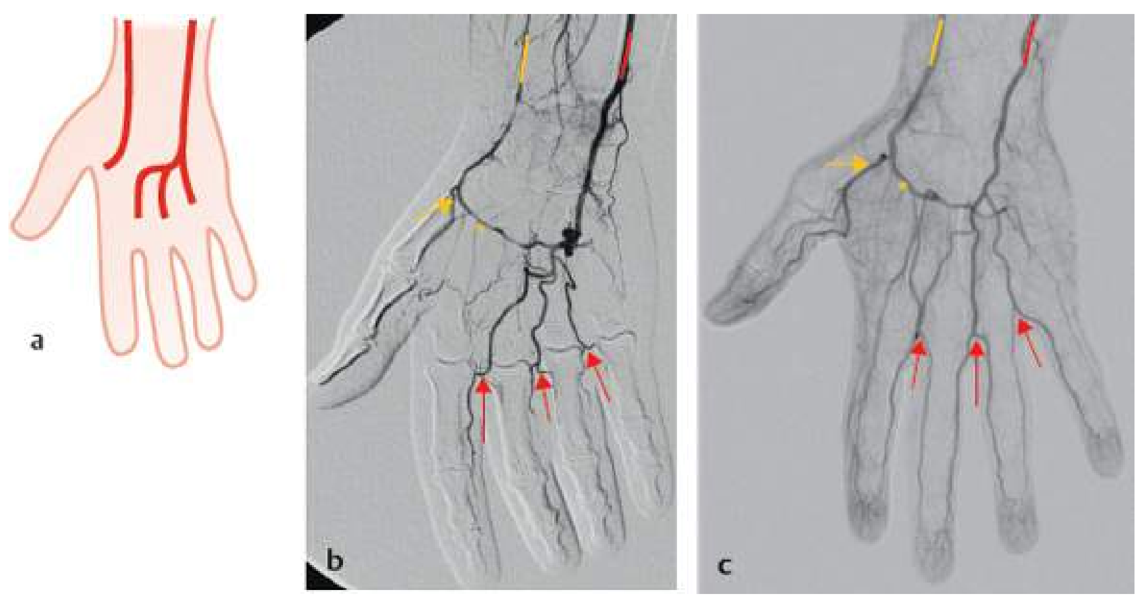

Fig. 36.6 The first originates from the radial, the others from the ulnar artery (13%). Schematic (**a**) and DSA from two different patients (**b,c**). Angiogram (**c**) was taken after intra-arterial vasodilation. Radial artery (yellow line); deep palmar arch (yellow asterisk); digital artery originating from radial artery (yellow arrow); ulnar artery (red line); digital arteries originating from ulnar artery (red arrows).

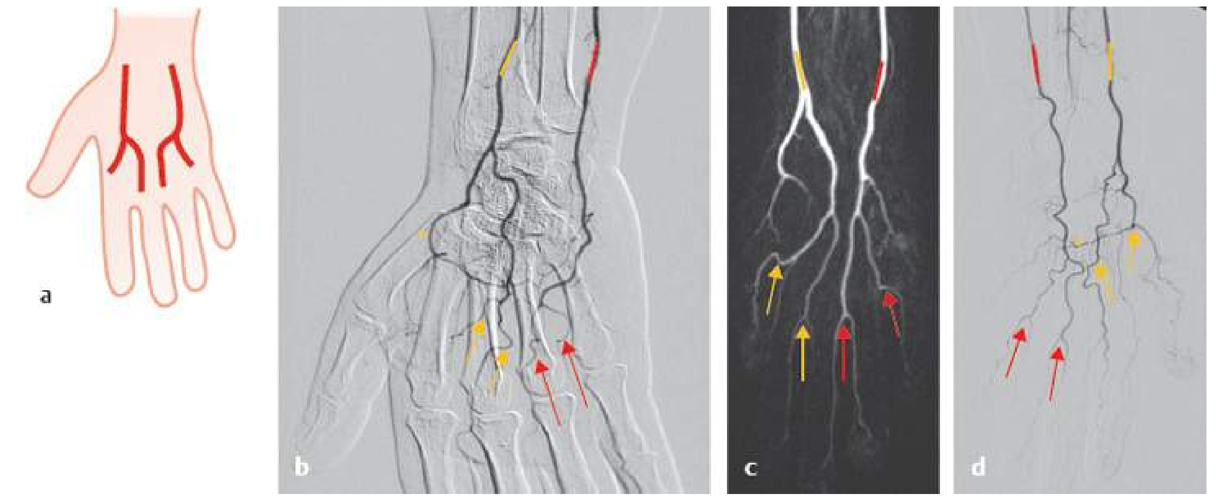

Fig. 36.7 The first two common palmar digital arteries originate from the radial, the other two from the ulnar artery (3%). Schematic (**a**) and radiographic images from three different patients demonstrating the variability of the anatomic variant (**b-d**). ***Patient 1***: DSA (**b**). ***Patient 2***: contrast-enhanced MR angiography, MIP (**c**). ***Patient 3***: DSA (**d**). **1** Radial artery; **2** ulnar artery; **3** digital arteries originating from ulnar artery; **4** digital arteries originating from radial artery; **5** deep palmar arch.

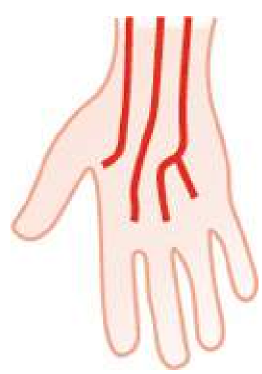

Fig. 36.8 The median artery continues as the second common palmar digital artery (1%). Schematic.

Fig. 36.9 The first two common palmar digital arteries are branches of the median artery, the others branch from the ulnar artery (4%). Schematic.

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37 Deep Palmar Arch and Palmar Digital Arteries

B. Meyer, L. Sonnow

37.1 Deep Palmar Arch

In about two-thirds of all cases, the ulnar artery has two deep palmar branches. The more proximal branch runs to the hypothenar muscles and rarely comes into contact with the deep palmar arch (**Fig. 37.2**). The additional supply of the interosseous artery to the deep palmar branch is sometimes of practical importance: if the radial and ulnar arteries are obliterated distal to the beginning of the common interosseous artery, the hand can be sufficiently supplied with blood by the anterior interosseous artery (**Fig. 37.3**). Some case reports of this situation have been published. As both palmar arches supply the same area, it is quite obvious that if one arch is very prominent, the other will be small.[1–10]

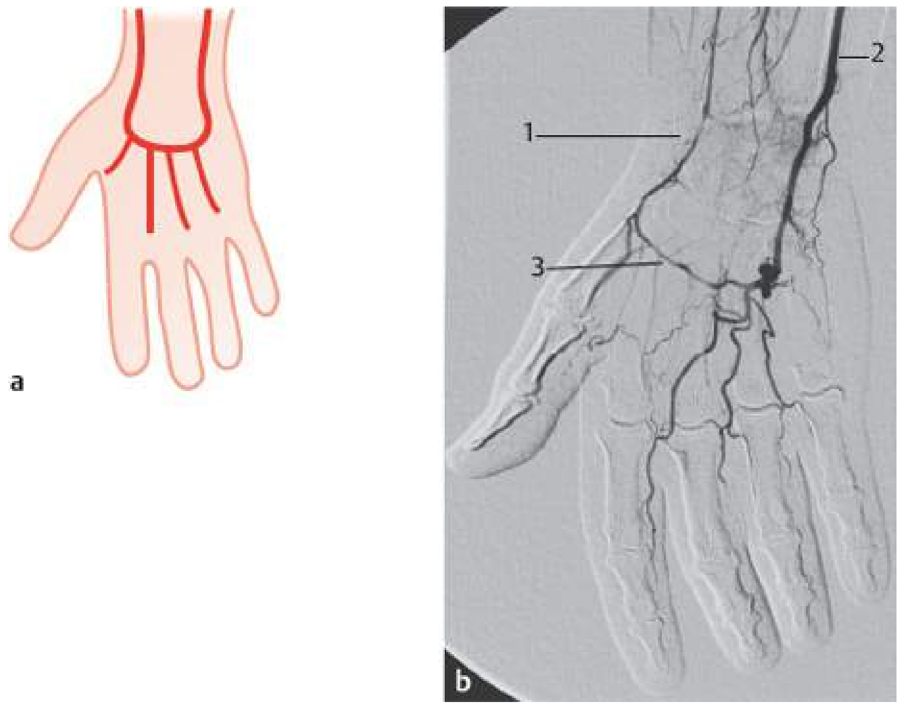

Fig. 37.1 The ulnar artery has one deep palmar branch to the arch (79%). Schematic (**a**) and DSA (**b**). **1** Radial artery; **2** ulnar artery; **3** deep palmar arch.

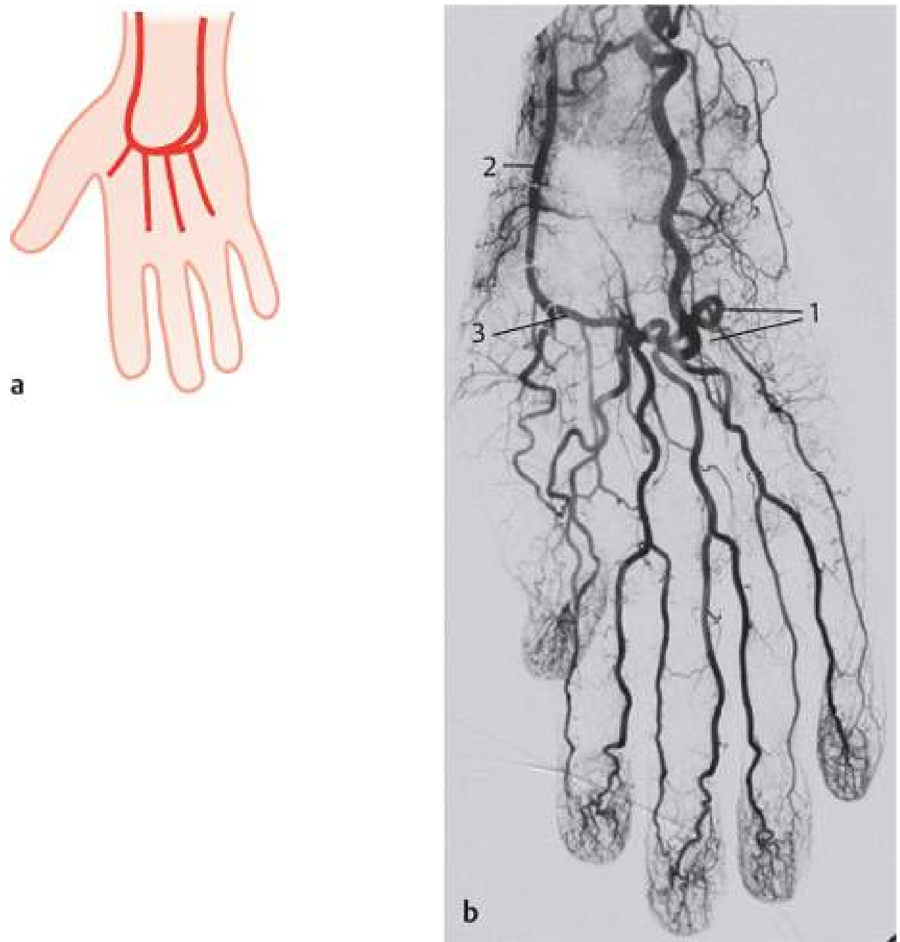

Fig. 37.2 The ulnar artery has two deep palmar branches (13%). Schematic (**a**) and DSA (**b**). **1** Ulnar artery with two deep palmar branches; **2** radial artery; **3** deep palmar arch.

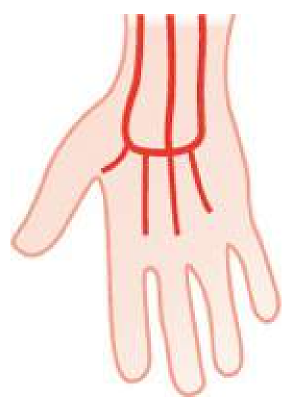

Fig. 37.3 The anterior interosseous artery also supplies the deep

arch (5%). Schematic.

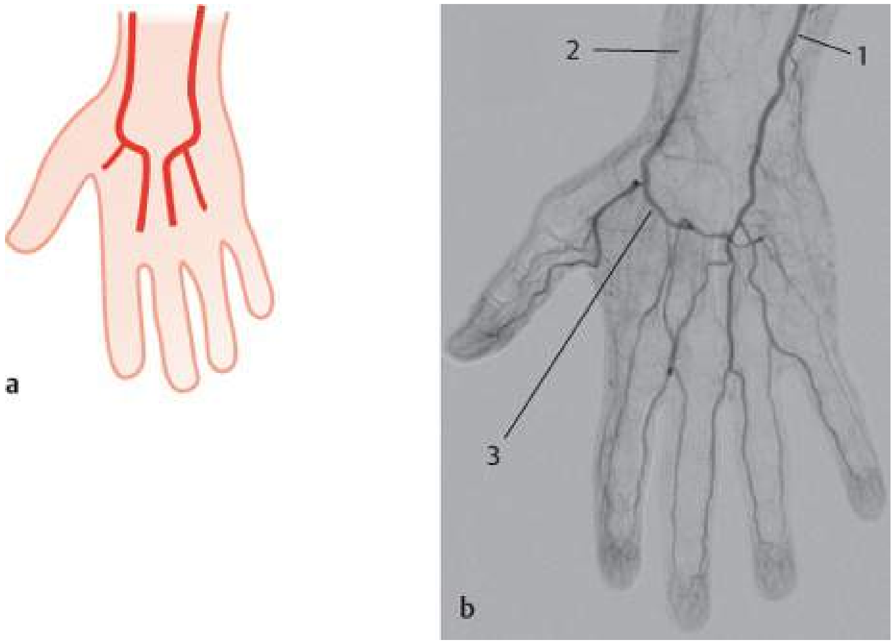

Fig. 37.4 The deep palmar arch is incomplete (3%). Schematic (**a**) and DSA after vasodilation (**b**). **1** Ulnar artery; **2** radial artery; **3** incomplete deep palmar arch.

37.2 Palmar Digital Arteries

According to the usual textbook description, the palmar metacarpal arteries from the deep arch unite with the common palmar digital arteries from the superficial palmar arch. Thus, both arches supply the fingers. However, this is valid for only 30% of all cases, and in a further 10%, the palmar metacarpal arteries anastomose with the proper palmar digital arteries. In the other 60%, there is no functional anastomosis.[1,6,11,12]

Many more combinations of anomalies are possible, for individual common palmar digital arteries can be absent and some metacarpal arteries are not always present. The first palmar metacarpal artery is normally very prominent and has a proper name—the princeps pollicis artery. It also has a branch to the index finger.

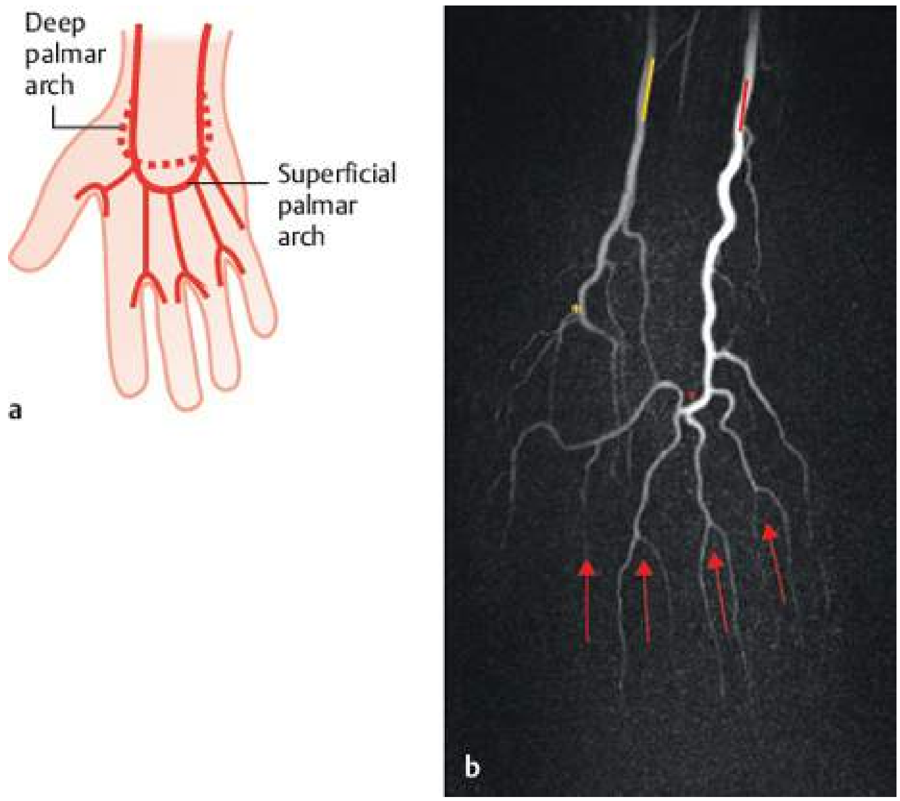

Fig. 37.5 Four common palmar digital arteries derive from the superficial palmar arch (77%). Schematic (**a**) and contrast-enhanced MRA, MIP (**b**). Radial artery (yellow line); deep palmar arch (yellow asterisk); ulnar artery (red line); superficial palmar arch (red asterisk); common pamar digital arteries (red arrows).

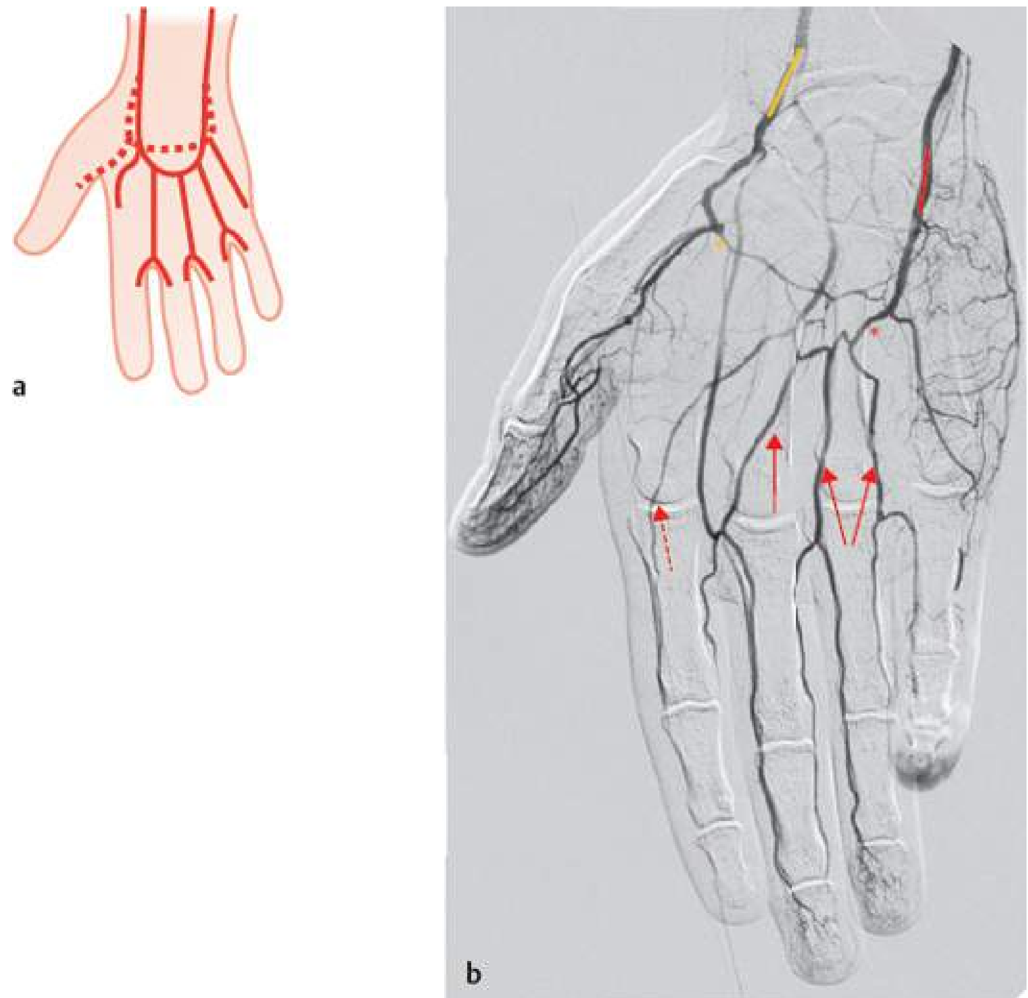

Fig. 37.6 Three common palmar digital arteries and a proper palmar digital artery to the thumb or index finger originate from the superficial palmar arch (10%). Schematic (**a**) and DSA (**b**). Radial artery (yellow line); deep palmar arch (yellow asterisk); ulnar artery (red line); superficial palmar arch (red asterisk); proper palmar digital artery (dashed red arrow); common palmar digital arteries (red arrows).

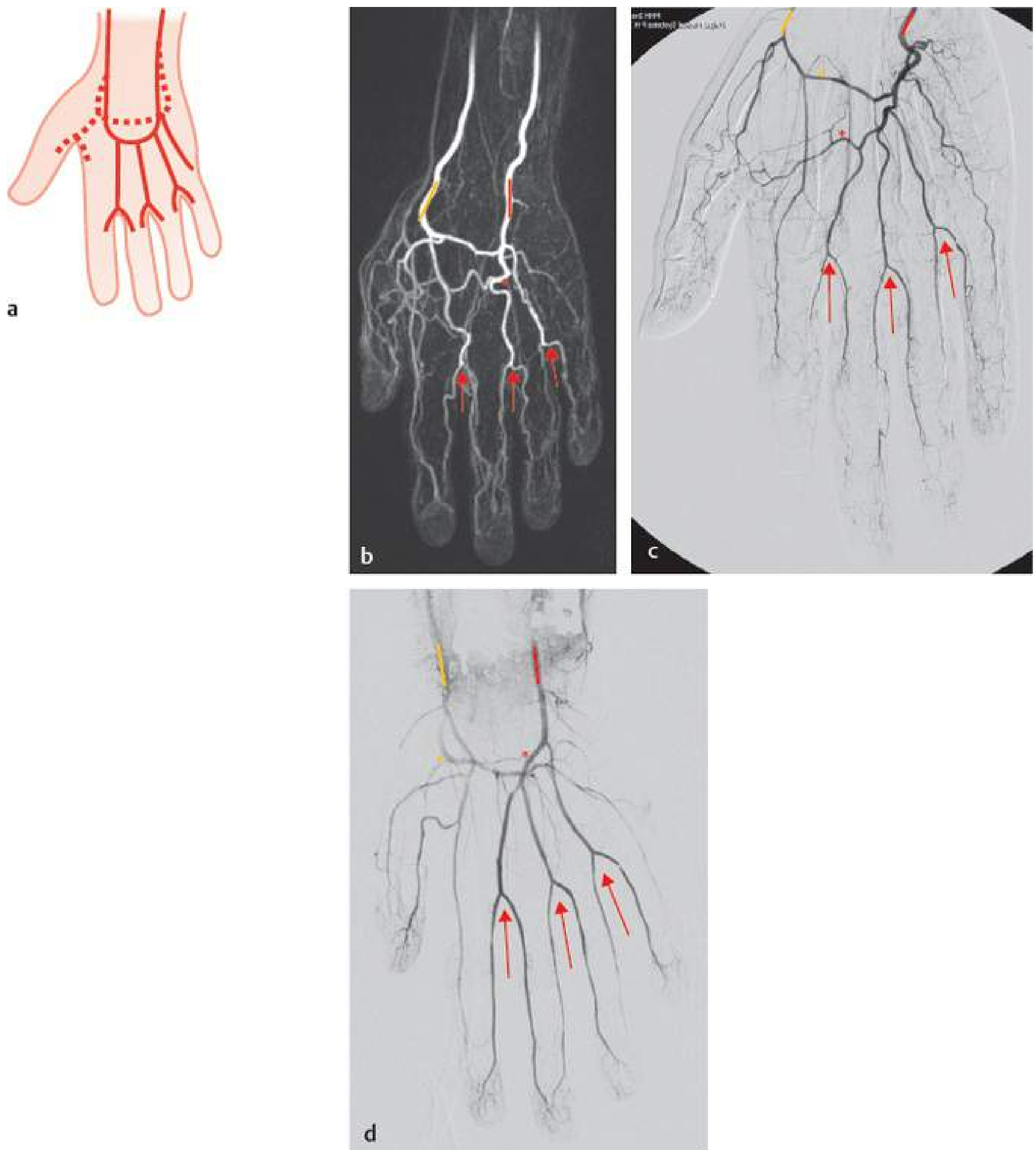

Fig. 37.7 Only three common palmar digital arteries derive from the superficial palmar arch (11%). Schematic (**a**) and radiographic images from three different patients (**b–d**). ***Patient 1***: Contrast-enhanced MRA, MIP (**b**). ***Patient 2***: DSA (**c**). ***Patient 3***: DSA (**d**). Radial artery (yellow line); ulnar artery (red line); superficial palmar arch (red asterisk); common palmar digital arteries (red arrows); deep palmar arch (yellow asterisk).

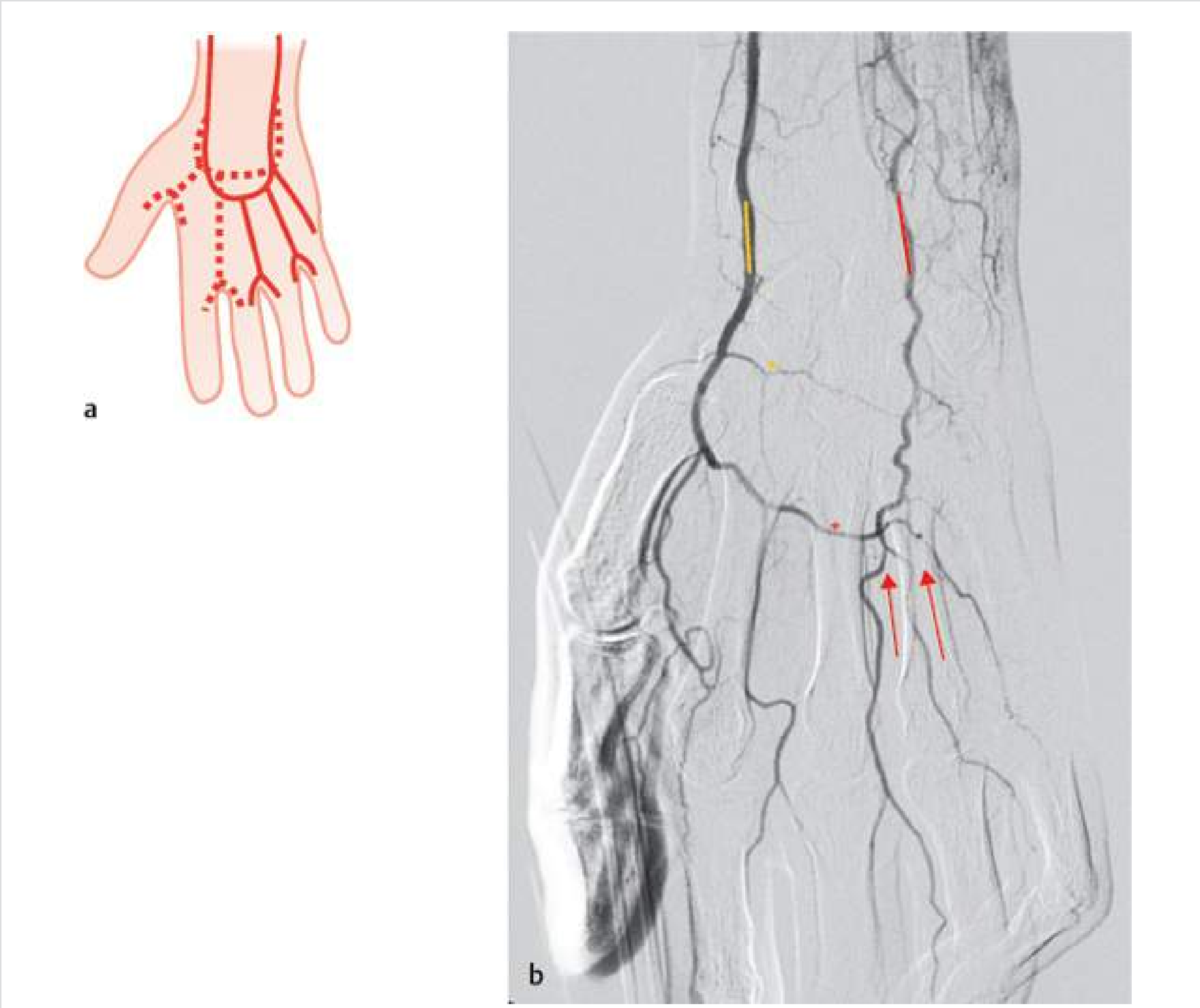

Fig. 37.8 Only two common palmar digital arteries derive from the superficial palmar arch (2%). Schematic (**a**) and DSA (**b**). Radial artery (yellow line); ulnar artery (red line); superficial palmar arch (red asterisk); common palmar digital arteries (red arrows); deep palmar arch (yellow asterisk).

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38 Arteries on the Dorsal Side of the Hand

B. Meyer, L. Sonnow

38.1 Dorsal Arterial Net of the Hand

The net of arteries on the dorsal side of the hand is not as important as the palmar arches and hard to visualize by angiography. The dorsal side of the fingers is supplied by the perforating branches from the palmar arteries (for the proximal parts of the fingers) and by branches of the proper palmar digital arteries for the middle and distal segments of the fingers. The arteries of the fingers follow a course similar to that of the nerves. In most cases, the posterior and anterior interosseous arteries take part in the blood supply of the dorsal side of the hand. The anterior interosseous artery sends a branch through the interosseous membrane to the dorsal side, where it unites with the posterior interosseous artery.[1–5]

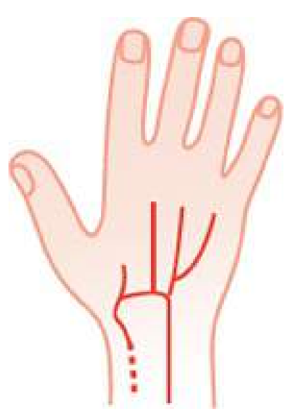

Fig. 38.1 Radiointerosseous type (50%). Schematic.

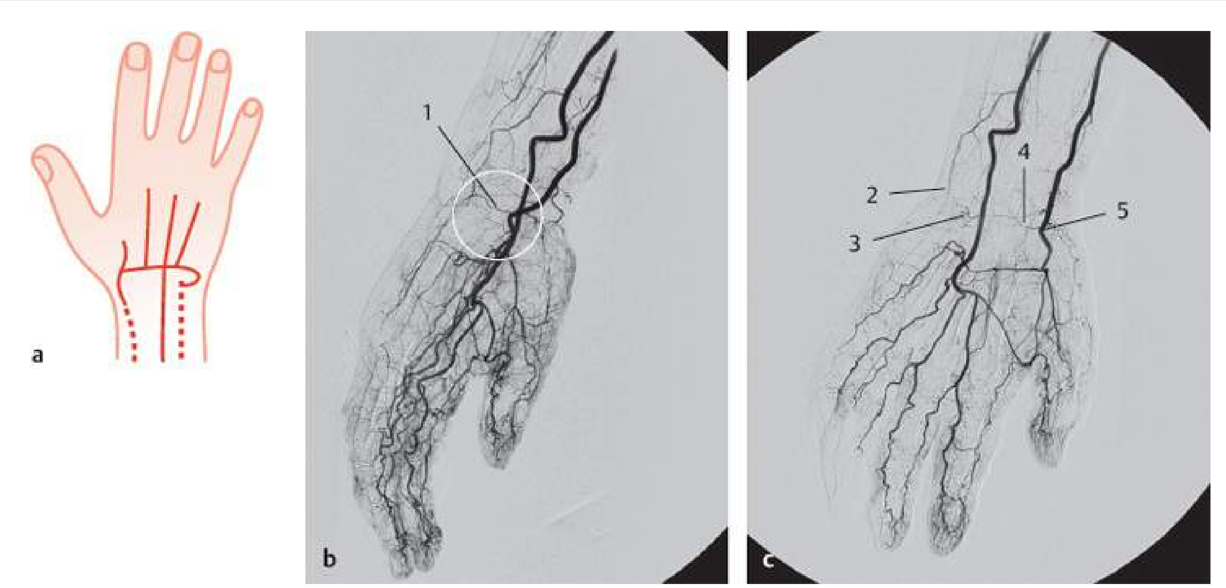

Fig. 38.2 Radiointerosseoulnar type (30%). Schematic (**a**), lateral DSA (**b**), and frontal DSA (**c**). **1** Dorsal net of arteries; **2** ulnar supply; **3** interosseous supply; **4** dorsal net of arteries; **5** radial supply.

Fig. 38.3 Radial type (8%). Schematic.

Fig. 38.4 Radioulnar type (5%). Schematic.

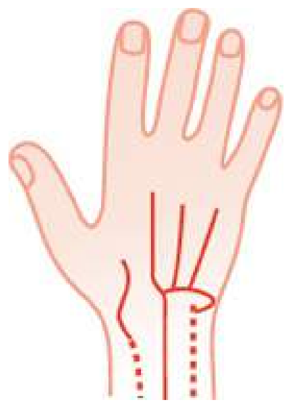

Fig. 38.5 Interosseoulnar type (3%). Schematic.

Fig. 38.6 No arterial net on the dorsal side (4%). Schematic.

38.2 Radial Artery

The possibilities outlined for the course of the radial artery can be further subdivided according the position of the long radial extensor muscle in relation to the tendon: in the type shown in **Fig. 38.7**, the radial artery almost always runs on the radial side, and in the types shown in **Fig. 38.8**, **Fig. 38.9**, and **Fig. 38.10**, it often runs on the ulnar side.

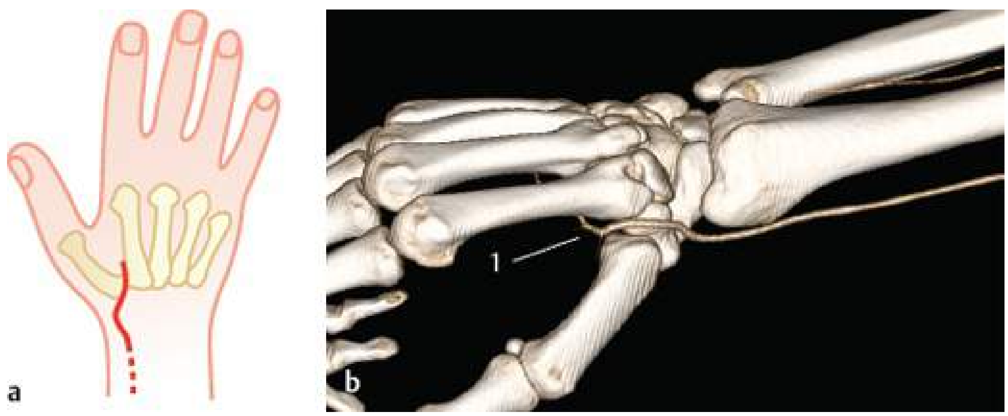

Fig. 38.7 The main stem pierces the first metacarpal interosseous space (96%). Schematic (**a**) and VR CTA (**b**). **1** Radial artery.

Fig. 38.8 The main stem pierces the second metacarpal interosseous space (1%). Schematic.

Fig. 38.9 The main stem divides and the branches run as in Fig. 38.7 and Fig. 38.8, respectively (2%). Schematic.

Fig. 38.10 A superficial radial artery: the normal radial artery pierces the second metacarpal interosseous space (1%). Schematic.

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Part V

Head and Spinal Cord

39 Subclavian Artery

F. Goetz, A. Giesemann

In this chapter, some rare combinations of trunk formations have not been included. A separate origin of the inferior thyroid, suprascapular, and transverse cervical artery occurs in about 5% of all cases. A similar frequency has been described for a separate origin of the deep cervical and the supreme intercostal artery, which are the main branches of the costocervical trunk. [1–8]

39.1 Variations of the Arteries from the Distal Subclavian Artery (85%)

Fig. 39.1 “Normal situation” as shown in textbooks (30%). The thyrocervical trunk is formed by the inferior thyroid, suprascapular, and transverse arteries of the neck. Schematic (**a**) and X-ray angiography, anterior view, right subclavian artery injection (**b**). **1** Ascending cervical artery; **2** vertebral artery; **3** internal thoracic artery.

Fig. 39.2 The internal thoracic artery originates from the thyrocervical trunk (10%). Schematic.

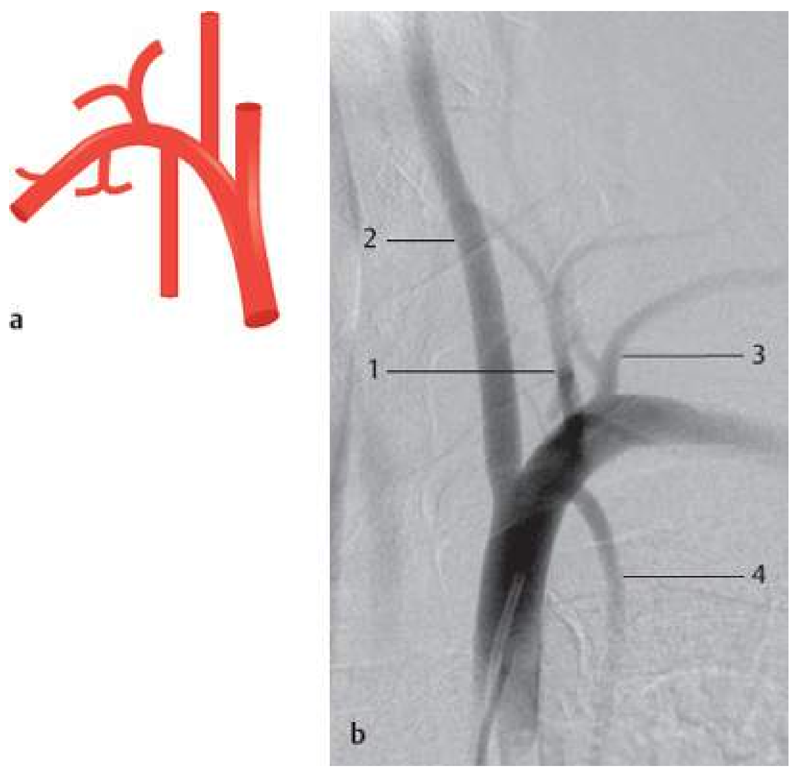

Fig. 39.3 Only the inferior thyroid and the suprascapular artery

form a common stem (30%). Schematic (**a**) and X-ray angiography, anterior view, left subclavian artery injection (**b**). **1** Thyrocervical trunk; **2** vertebral artery; **3** costocervical trunk; **4** internal thoracic artery.

Fig. 39.4 Common trunk of the inferior thyroid, suprascapular, and internal thoracic arteries (8%). Schematic.

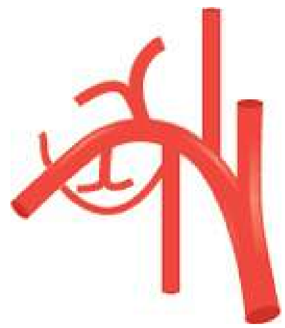

Fig. 39.5 Two trunks: the inferior thyroid with the suprascapular artery and the transverse colli with the internal thoracic artery (1%). Schematic.

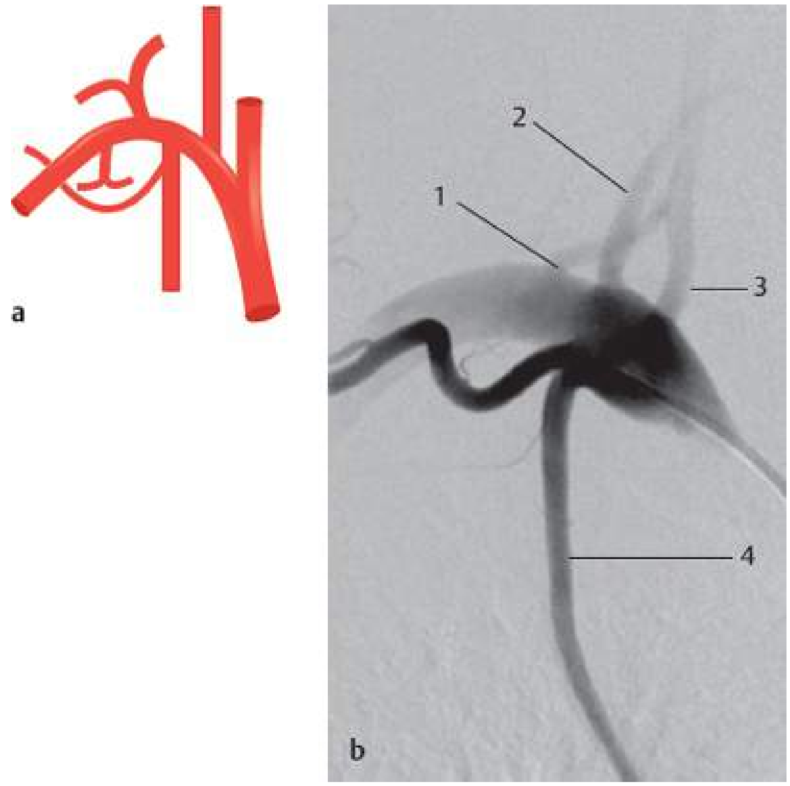

Fig. 39.6 Two trunks: the inferior thyroid with the transverse colli arteries and the suprascapular with the internal thoracic arteries (4%). Schematic (**a**) and X-ray angiography, anterior view, right subclavian artery injection (**b**). **1** Ascending cervical artery; **2** inferior thyroid artery; **3** vertebral artery; **4** internal thoracic artery.

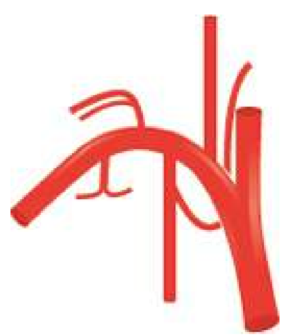

Fig. 39.7 Two trunks: inferior thyroid with the internal thoracic arteries and suprascapular with the transverse colli arteries (1%). Schematic.

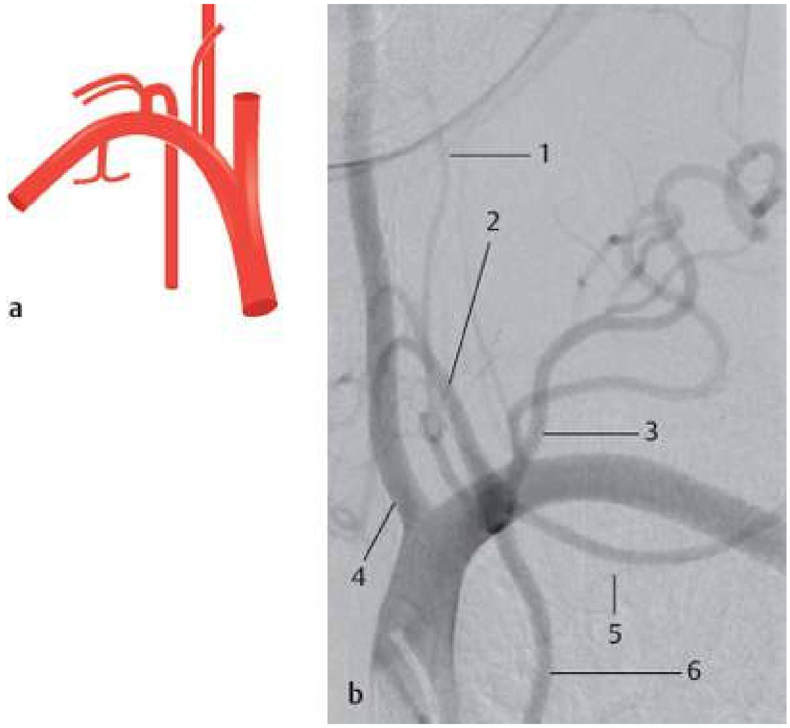

Fig. 39.8 Common trunk of the suprascapular, transverse colli, and internal thoracic arteries (1%). Schematic (**a**) and X-ray angiography, anterior view, left subclavian artery injection (**b**). **1** Ascending cervical artery; **2** inferior thyroid artery; **3** suprascapular artery; **4** vertebral artery; **5** transverse cervical artery; **6** internal thoracic artery.

39.2 Participation of the Vertebral Artery and/or the Costocervical Trunk (10%)

Fig. 39.9 Costocervical trunk with the transverse colli artery (5%). Schematic.

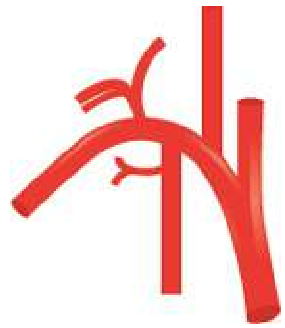

Fig. 39.10 Costocervical trunk with the internal thoracic artery (1%). Schematic.

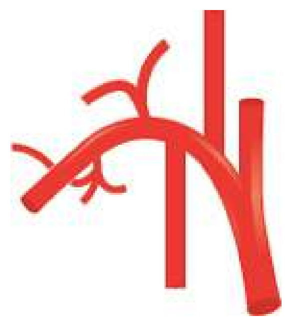

Fig. 39.11 Costocervical trunk with the suprascapular artery (1%). Schematic.

Fig. 39.12 Costocervical trunk with the inferior thyroid artery (1%). Schematic.

Fig. 39.13 Costocervical trunk with the inferior thyroid and suprascapular arteries (1%). Schematic.

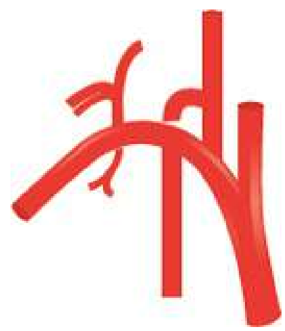

Fig. 39.14 Costocervical trunk with the vertebral artery (<1%). Schematic.

Fig. 39.15 Vertebral artery with the inferior thyroid artery (<1%). Schematic (**a**); X-ray angiography, anterior view, right inferior thyroid artery injection with reflux to the right vertebral and subclavian arteries (**b**); and X-ray angiography, anterior view, left vertebral artery injection, origin of the left vertebral artery from the aortic arch (see **Fig. 41.5**) (**c**). **1** Vertebral artery; **2** inferior thyroid artery; **3** internal thoracic artery; **4** left vertebral artery, cervical part; **5** left vertebral artery, origin from the aortic arch.

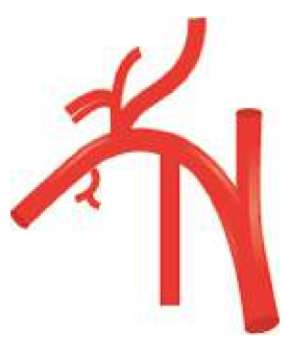

Fig. 39.16 Vertebral artery with the thyrocervical trunk (<1%). Schematic.

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40 Inferior Thyroid Artery

F. Goetz, A. Giesemann

The blood supply to the thyroid gland is of great clinical relevance. In addition to the inferior thyroid arteries, the superior thyroid arteries (see **Figs. 42.2–42.9**) and the arteria thyroidea ima (see **Fig. 2.22**) show considerable variations.[1-10]

40.1 Origin from the Subclavian Artery Medial to the Anterior Scalenus Muscle (95%)

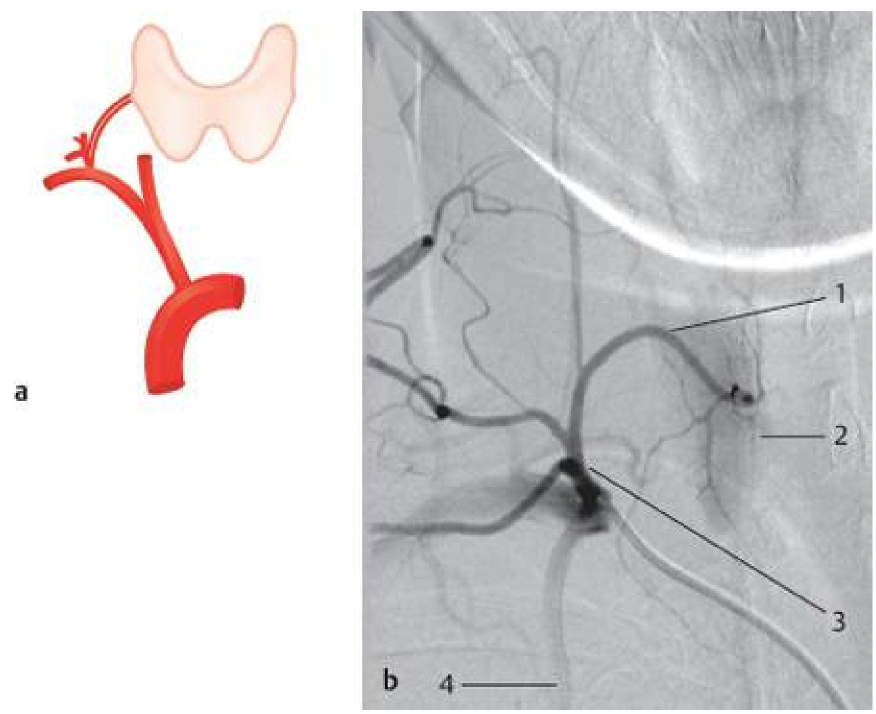

Fig. 40.1 From the thyrocervical trunk (normal case as shown in textbooks) (85%). Schematic (**a**) and DSA (**b**), injection of the thyrocervical trunk. In **b**, the inferior thyroid artery gives a thyroid

parenchymal blush. There is only faint opacification of the internal thoracic artery and the costocervical trunk. **1** Inferior thyroid artery; **2** thyroid parenchymal blush; **3** thyrocervical trunk; **4** internal thoracic artery.

Fig. 40.2 Direct from the subclavian artery (8%). Schematic.

Fig. 40.3 Common stem with the vertebral artery (1%). Schematic.

Fig. 40.4 Common stem with the internal thoracic artery (1%). Schematic.

40.2 Origin from the Subclavian Artery, Posterior or Lateral to the Anterior Scalenus Muscle (1%)

Fig. 40.5 Common origin with the suprascapular artery or the costocervical trunk (<1%). Schematic.

Fig. 40.6 Direct from the subclavian artery (0.1%). Schematic.

40.3 Origin from the Common Carotid Artery (1%)

Most of these cases occur on the right side, but the inferior thyroid artery can also originate from the bifurcation of the brachiocephalic trunk.

Fig. 40.7 Origin from the common carotid artery (1%). Schematic.

40.4 Absence of the Inferior Thyroid Artery (3%)

In this variation, the superior thyroid artery or the arteria thyroidea ima supplies the area of the inferior thyroid artery.

Fig. 40.8 Absence of the inferior thyroid artery (3%). Schematic.

40.5 Topographical Relationship to the Laryngeal Nerve[1,2,9,11]

Fig. 40.9 The recurrent laryngeal nerve is anterior to the inferior thyroid artery (30%). Schematic.

Fig. 40.10 The recurrent laryngeal nerve runs between the main branches of the inferior thyroid artery (45%). Schematic.

Fig. 40.11 The recurrent laryngeal nerve runs posteriorly to the inferior thyroid artery (24%). Schematic.

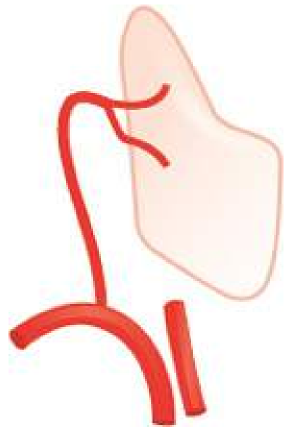

Fig. 40.12 There is no recurrent laryngeal nerve because it is a direct branch of the vagal nerve in cases of an arteria lusoria (see Fig. 2.22) (1%). Schematic.

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41 Vertebral Artery

F. Goetz, A. Giesemann

41.1 Origin

Although the number of anomalies on the right and left side seem to be comparable on the whole, there are major differences between sides within the different types. The left side shows a tendency to a more medial origin, the right side to a more lateral origin.[1–10]

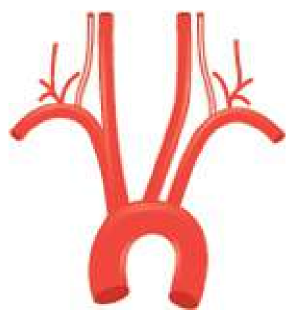

Fig. 41.1 Origin from the subclavian artery on the top of the arch, near the thyrocervical trunk (right side 90%; left side 90%). Schematic.

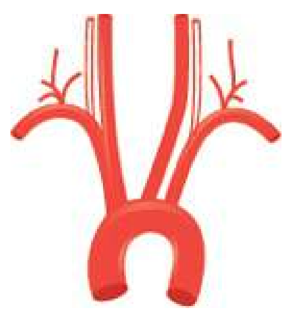

Fig. 41.2 Origin from the subclavian artery further medial, more than 2 cm from the thyrocervical trunk; on the right side, often

from the bifurcation of the brachiocephalic trunk (right side 4%; left side 3%). Schematic.

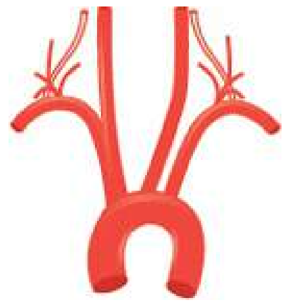

Fig. 41.3 Origin from the subclavian artery lateral to the thyrocervical trunk (right side 4%; left side <0.1%). Schematic.

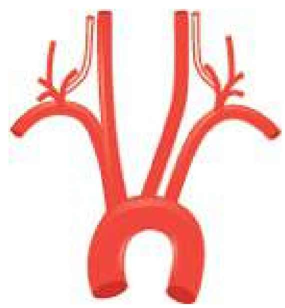

Fig. 41.4 Common origin with the thyrocervical trunk (right side <1%; left side 2%). Schematic.

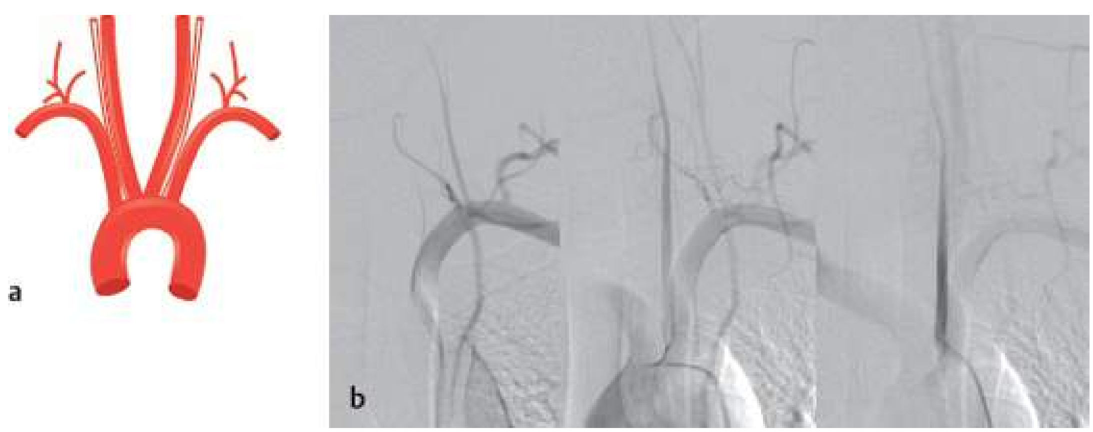

Fig. 41.5 Origin from the aortic arch (right side <0.1%; left side

4%). For different subtypes, see **Figs.2.12–2.19**. Schematic (**a**) and X-ray angiography, anterior view, left subclavian artery injection (**b**); because the catheter slipped out of the subclavian artery, the second frame looks like an aortic arch injection; finally the tip of the catheter is inside the origin of the left vertebral artery, which originates directly from the aortic arch.

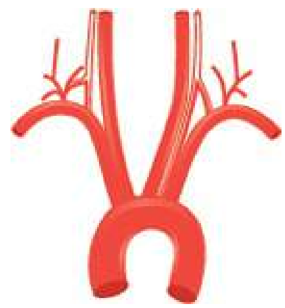

Fig. 41.6 Two roots from the aorta and subclavian artery or accessory vertebral arteries, also from the thyrocervical trunk (right side <1%; left side 1%). Schematic.

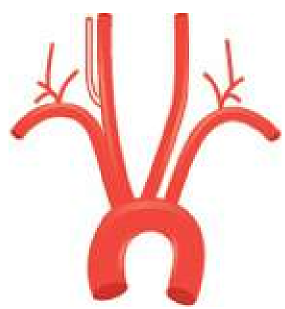

Fig. 41.7 Origin from the common carotid artery (right side <1%; left side 0%). Schematic.

41.2 Entrance into the Cervical Vertebral Column

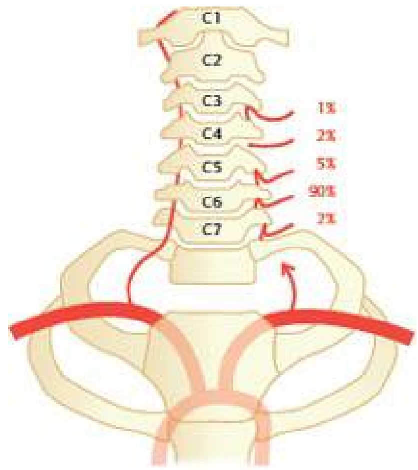

Fig. 41.8 Entrance into the cervical vertebral column. Schematic. The caudalmost transverse foramen through which the vertebral artery runs is indicated. On the left side, the vertebral artery enters the vertebral column more often through another transverse foramen than through that of C6 as generally stated in textbooks.[4,5]

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42 External Carotid Artery

F. Goetz, A. Giesemann

42.1 Bifurcation of the Common Carotid Artery

The division of the common carotid artery has often been related to the larynx. The height of the larynx is age-dependent, resulting in different heights of division of the common carotid artery according to age. It is more reliable to relate the bifurcation to the vertebral column to avoid age dependency. Differences of up to the height of one cervical vertebra have been described between the right and left side. Arch-like divisions are more common in higher divisions and divisions at acute angles more frequent in lower divisions.[1–3]

The references are given for anomalies of the carotid arteries in general[2,4–10] (see also **Figs. 2.3–2.28**) and for the branches and trunks of the external carotid artery. Many studies deal with more than one branch.[1,2,11–13]

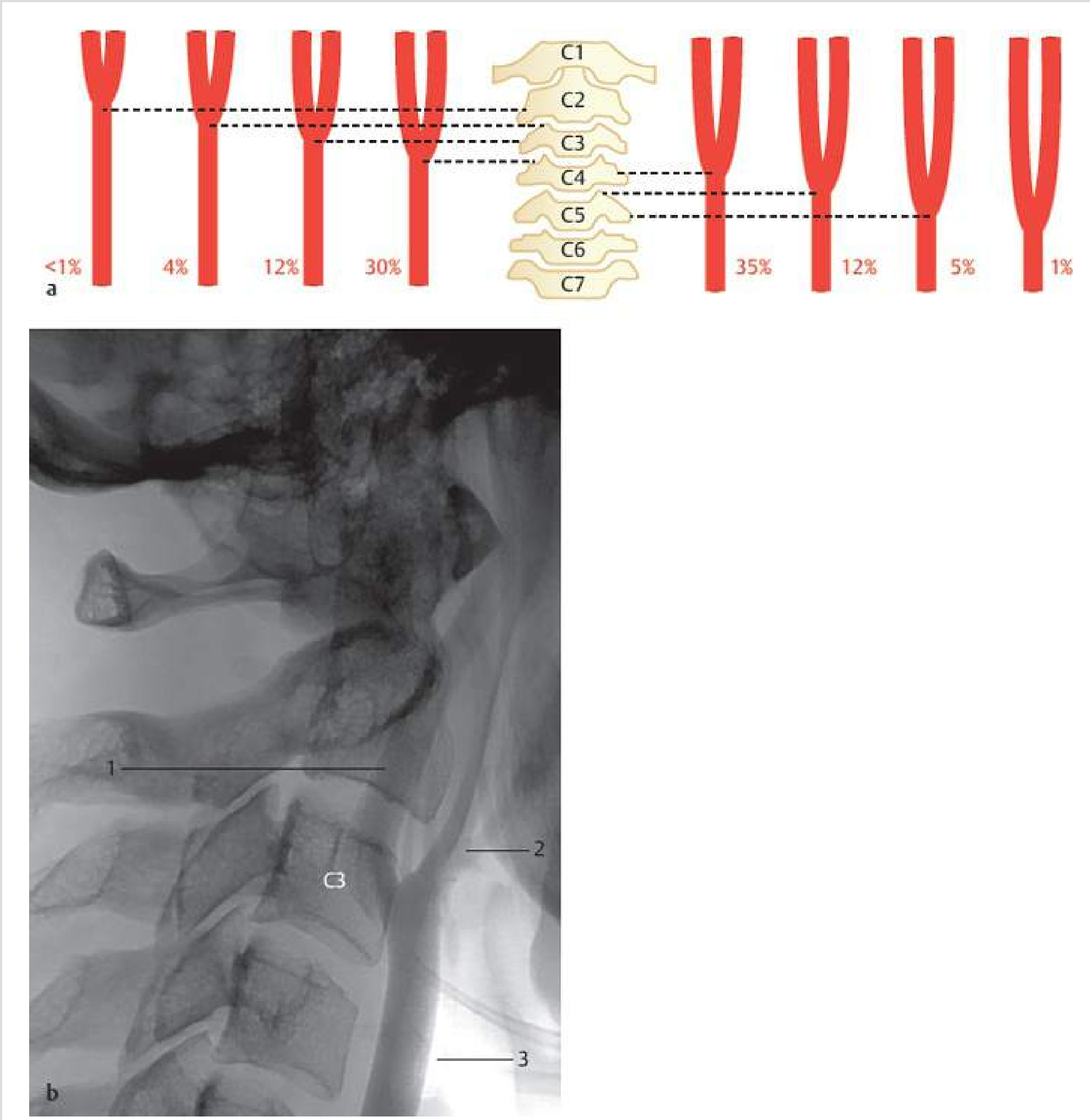

Fig. 42.1 Bifurcation of the common carotid artery. Schematic (**a**) and X-ray angiography, unsubtracted image, lateral view, common carotid artery injection (bifurcation at the level of C3) (**b**). **1** Internal carotid artery; **2** external carotid artery; **3** common carotid artery.

42.2 Superior Thyroid, Lingual, and Facial Arteries

42.2.1 Separate Origins (80%)

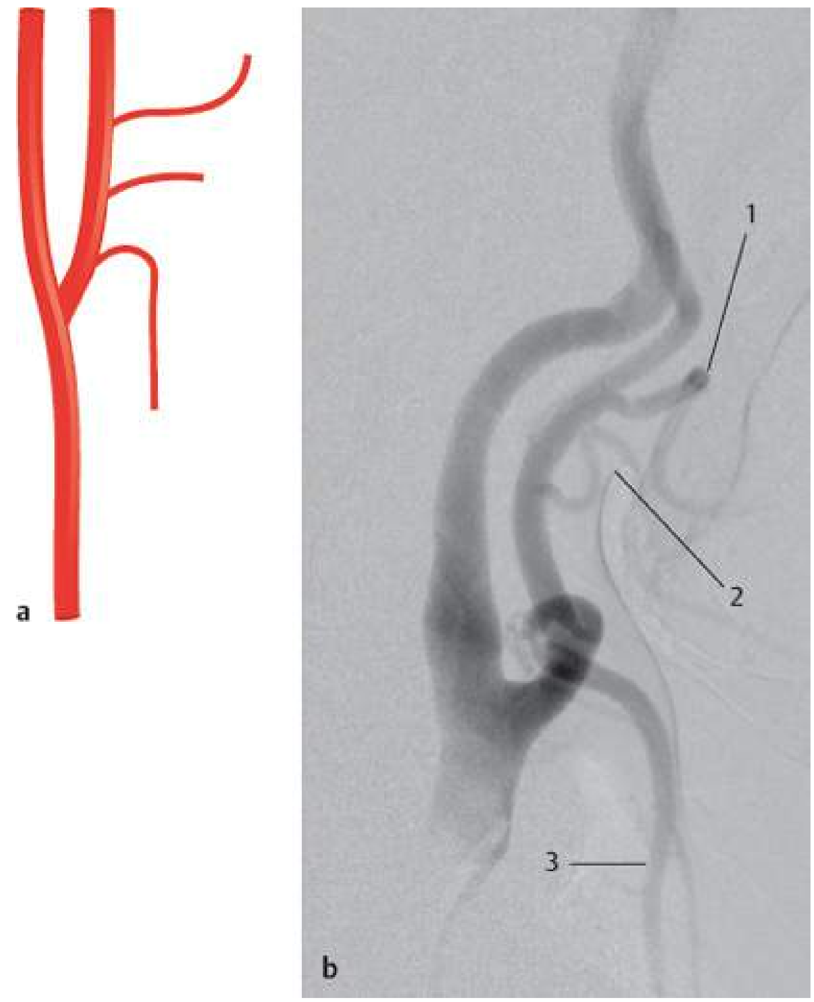

Fig. 42.2 All three arteries originate from the external carotid artery (50%). Schematic (**a**) and X-ray angiography, lateral view, common carotid artery injection (**b**). **1** Facial artery; **2** lingual artery; **3** inferior thyroid artery.

Fig. 42.3 The superior thyroid artery originates from the bifurcation of the common carotid artery (20%). This variation is more common on the left side than on the right side. Schematic (**a**) and X-ray angiography, lateral view, common carotid artery injection; note ectasia of the superior thyroid and occipital arteries (**b**). **1** Internal carotid artery; **2** internal maxillary artery; **3** occipital artery; **4** facial artery; **5** inferior thyroid artery.

Fig. 42.4 The superior thyroid artery originates from the common carotid artery (10%). This variation is considerably more common on the left side than on the right side, and it is more common in women than in men. Schematic (**a**), X-ray angiography, lateral view, left common carotid artery injection (**b**), and X-ray angiography, lateral view, left common carotid artery injection with origin of the superior thyroid from the common carotid and origin of a linguofacial trunk at the bifurcation level (**c**). **1** Internal maxillary artery; **2** facial artery; **3** lingual artery; **4** inferior thyroid artery.

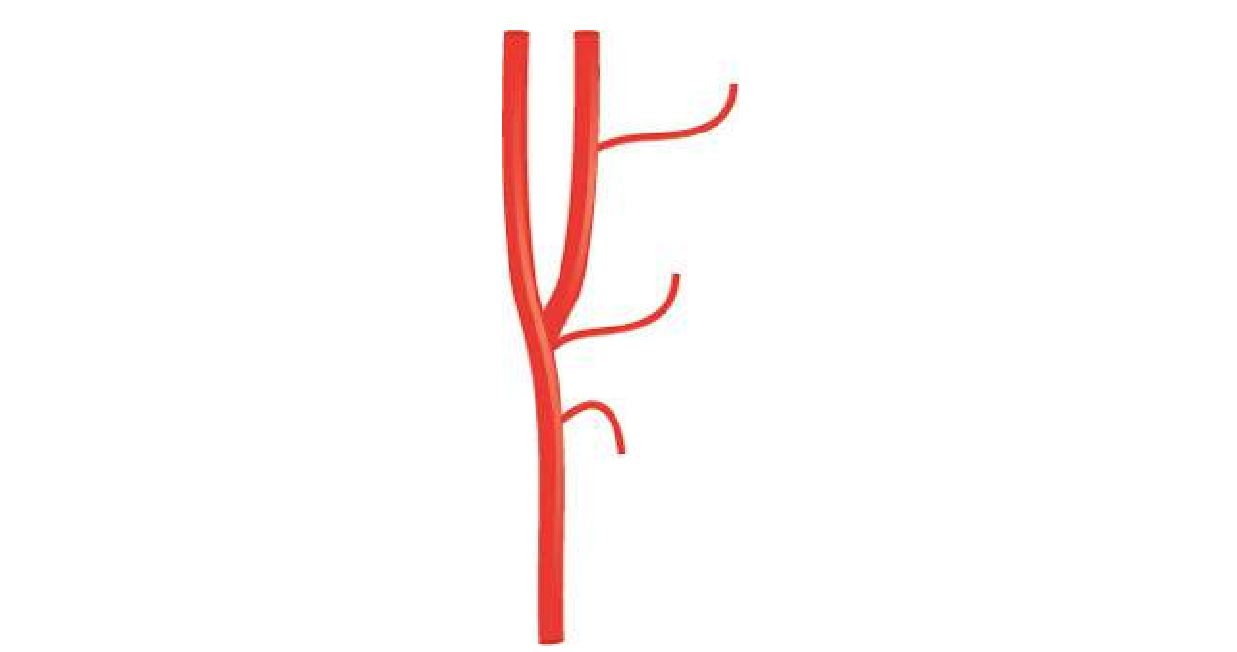

Fig. 42.5 The superior thyroid and lingual arteries originate from the common carotid artery (<1%). Schematic.

42.2.2 Trunk Formation (20%)

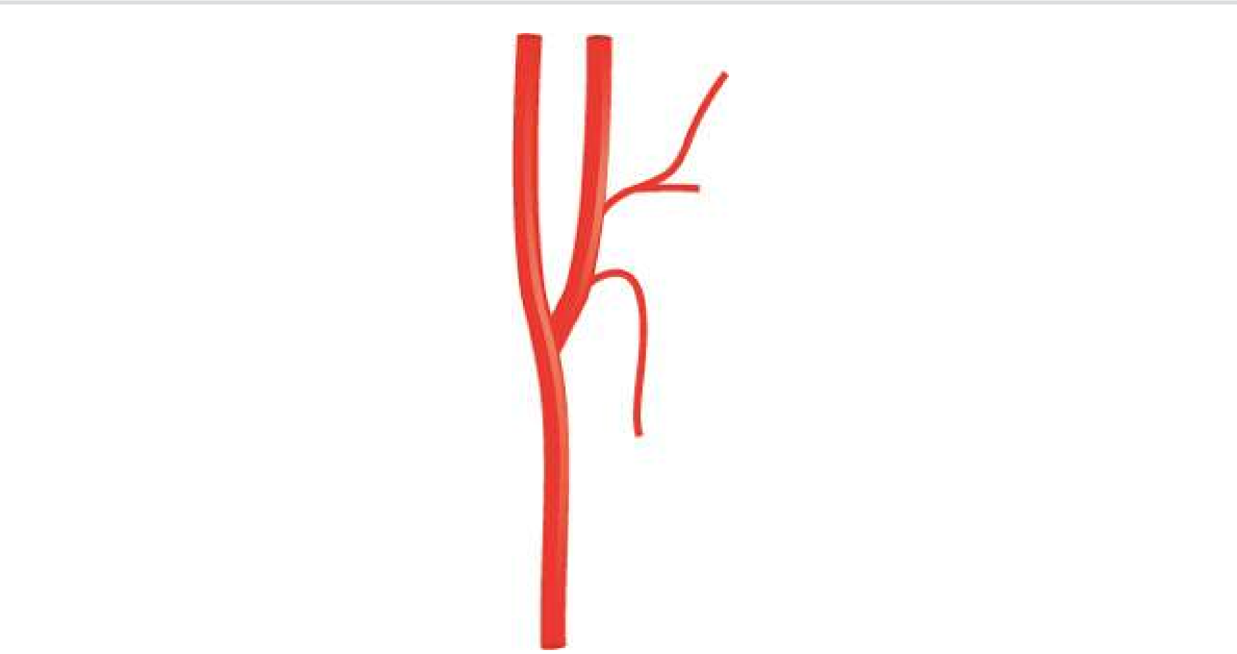

Fig. 42.6 Linguofacial trunk (always from the external carotid artery) (18%). The superior thyroid artery might derive from the

common carotid artery. Schematic.

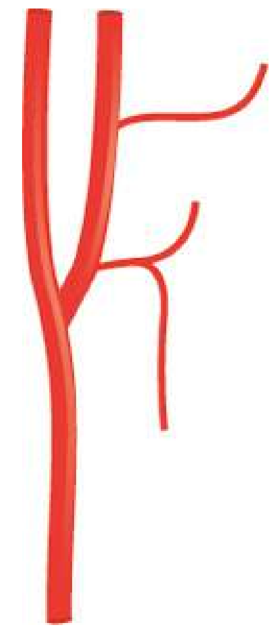

Fig. 42.7 Thyrolingual trunk from the external carotid artery (2%). Schematic.

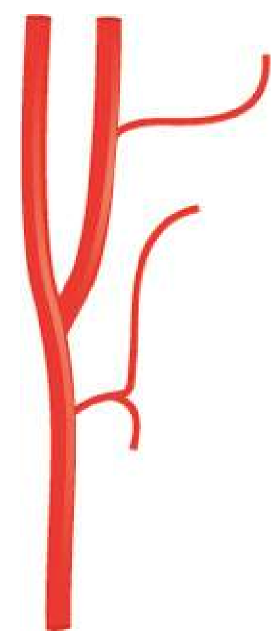

Fig. 42.8 Thyrolingual trunk from the common carotid artery (<0.1%). Schematic.

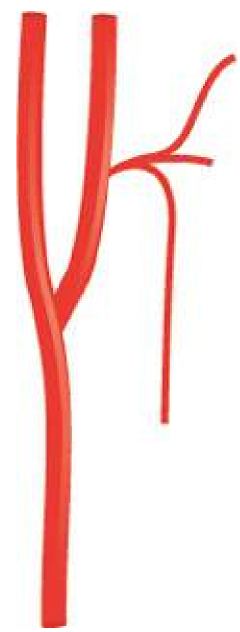

Fig. 42.9 Thyrolinguofacial trunk (always from the external carotid artery) (<1%). Schematic.

42.3 Superior Laryngeal Artery

42.3.1 Origin

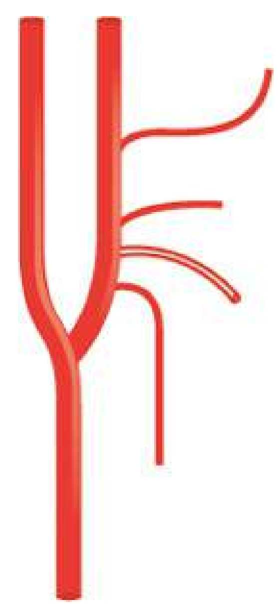

Fig. 42.10 From the external carotid artery (10%). Schematic.

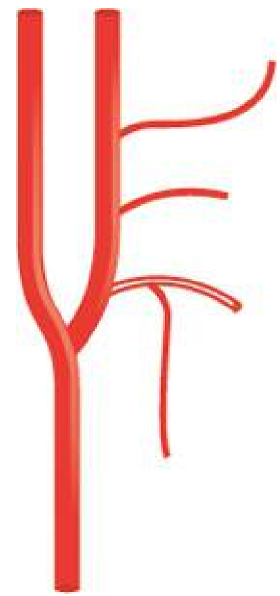

Fig. 42.11 From the superior thyroid artery (88%). Schematic.

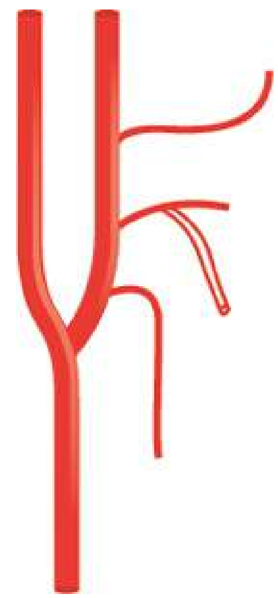

Fig. 42.12 From the lingual artery (1%). Schematic.

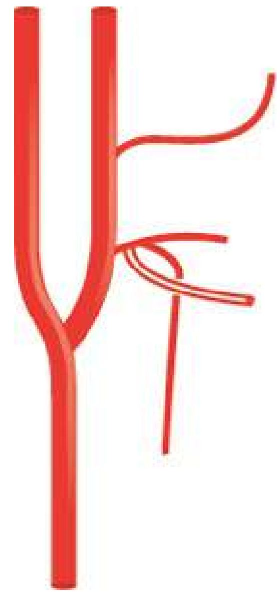

Fig. 42.13 From the thyrolingual or thyrolinguofacial trunk (1%). Schematic.

42.3.2 Course

Fig. 42.14 Through the thyrohyoid membrane (75%). Schematic.

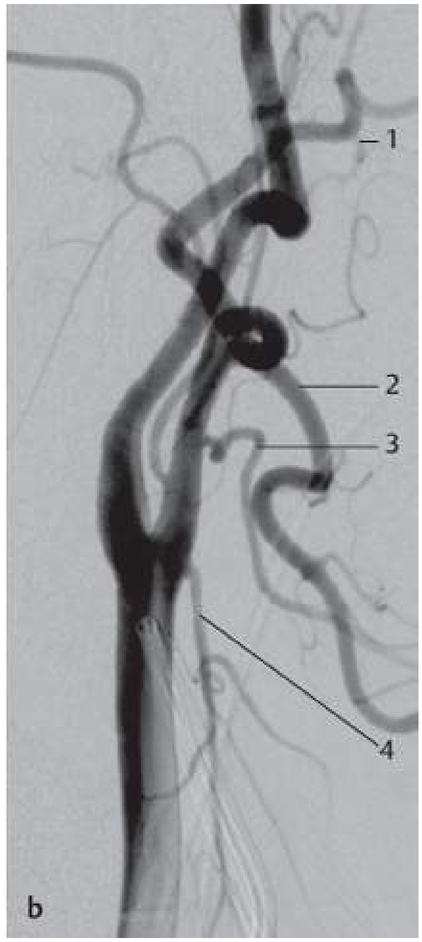

Fig. 42.15 Through a thyroid foramen (20%). Schematic (**a**) and X-ray angiography, lateral view, common carotid artery injection (**b**). **1** Internal maxillary artery; **2** facial artery; **3** lingual artery; **4** inferior thyroid artery with superior laryngeal artery.

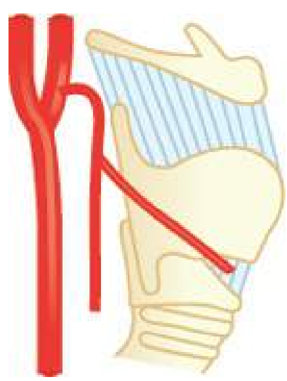

Fig. 42.16 Between the thyroid and cricoid cartilage into the

larynx (5%). Schematic.

42.4 Occipital and Posterior Auricular Arteries

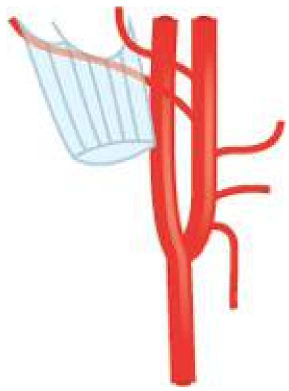

Fig. 42.17 The occipital and posterior auricular arteries originate separately from the external carotid artery (85%). Schematic.

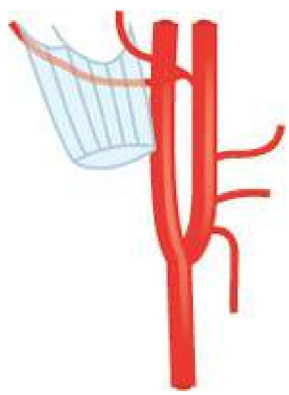

Fig. 42.18 Occipitoauricular trunk (14%). Schematic.

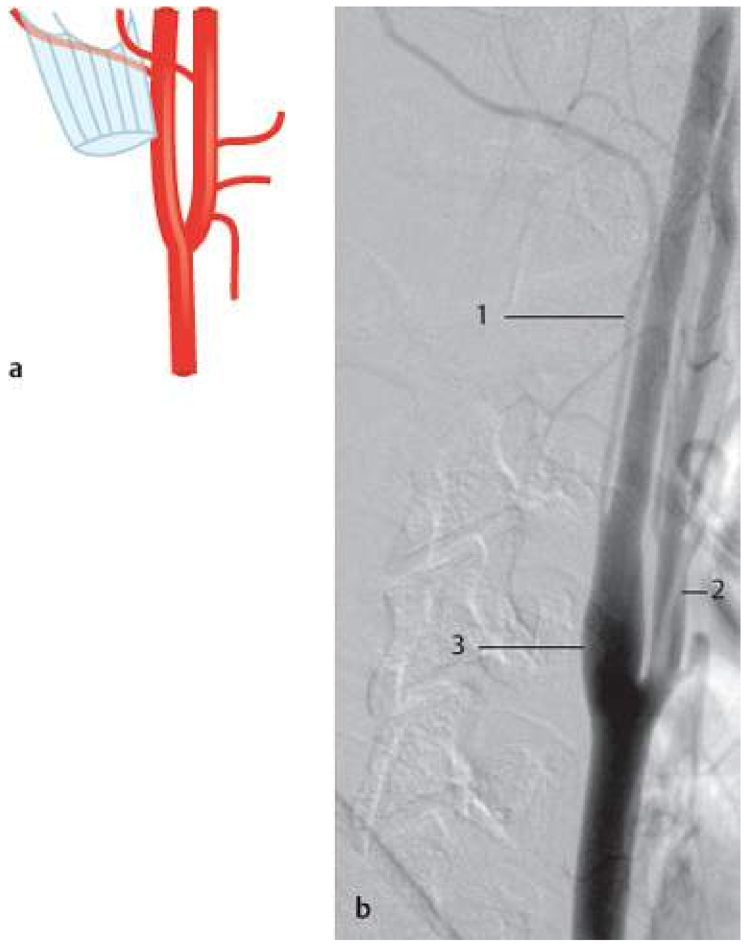

Fig. 42.19 The occipital artery originates from the internal carotid artery (<0.1%). Schematic (**a**) and X-ray angiography, lateral view, right common carotid artery injection (**b**). **1** Occipital artery; **2 e**xternal carotid artery; **3** bulb of the internal carotid artery.

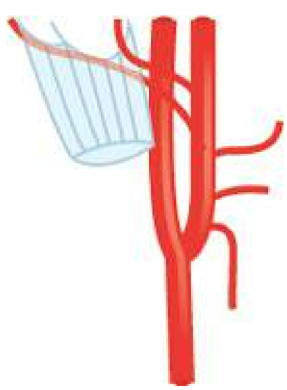

Fig. 42.20 A superficial occipital artery runs superficially to the

sternocleidomastoid muscle (1%). Schematic.

42.5 Ascending Pharyngeal Artery

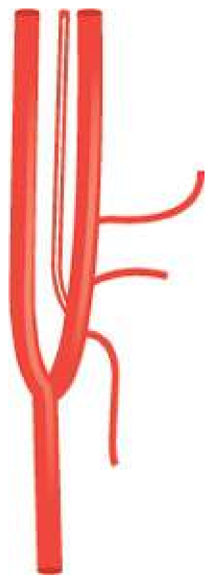

Fig. 42.21 Direct origin from the external carotid artery (70%). Schematic.

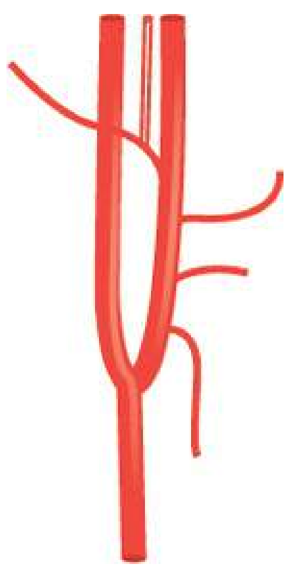

Fig. 42.22 Origin from the occipital artery (20%). Schematic.

Fig. 42.23 Origin from the facial artery (2%). Schematic.

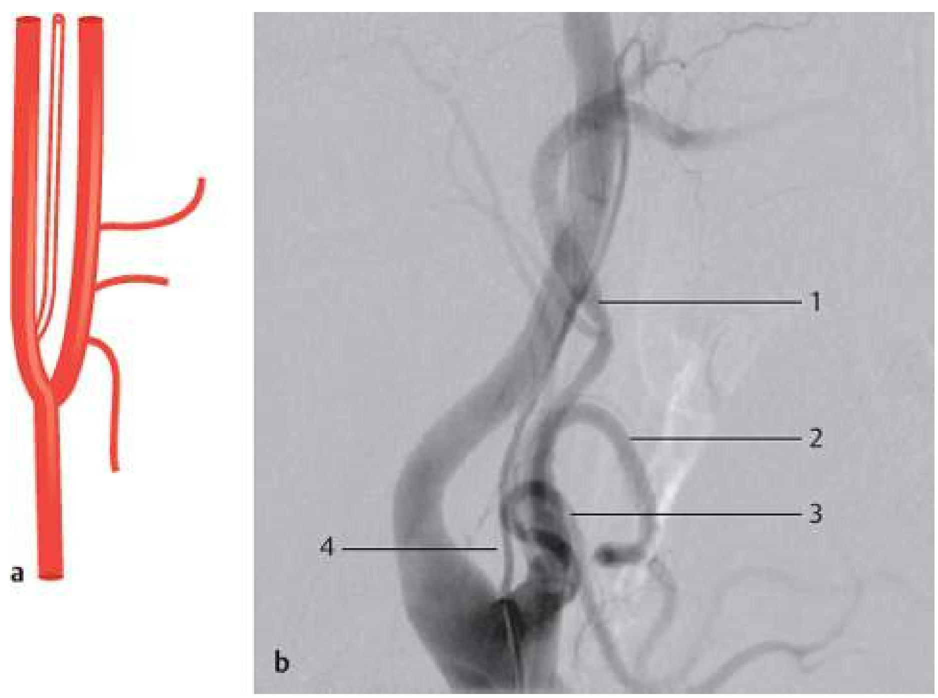

Fig. 42.24 Origin from the internal carotid artery (8%). Schematic (**a**) and X-ray angiography, lateral view, common carotid artery injection (**b**). **1** Internal maxillary artery; **2** facial artery; **3** lingual artery; **4** ascending pharyngeal artery.

42.6 Ascending Palatine Artery

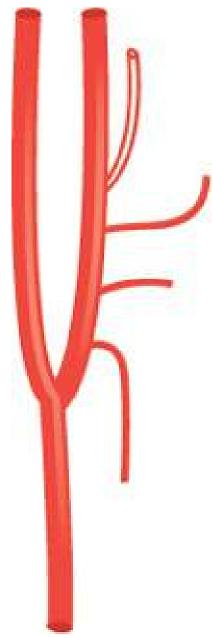

Fig. 42.25 Direct origin from the external carotid artery (20%). Schematic.

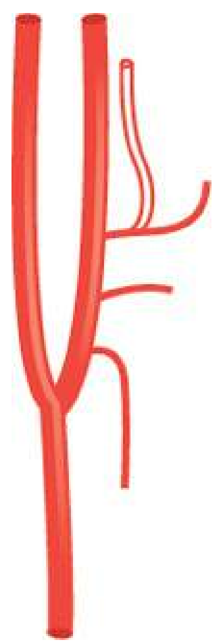

Fig. 42.26 Origin from the facial artery (70%). Schematic.

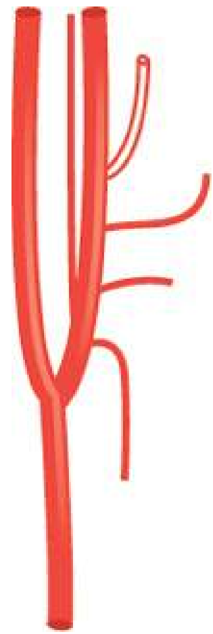

Fig. 42.27 Origin from the ascending pharyngeal artery (8%). Schematic.

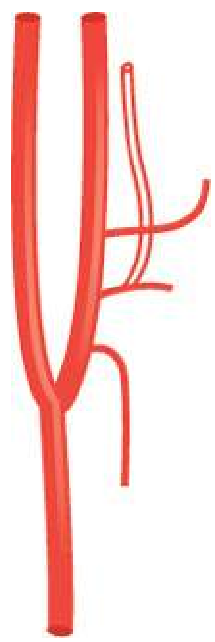

Fig. 42.28 Origin from the lingual artery (1%). Schematic.

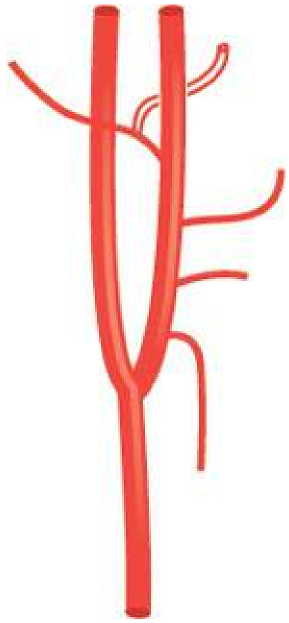

Fig. 42.29 Origin from the occipital artery (1%). Schematic.

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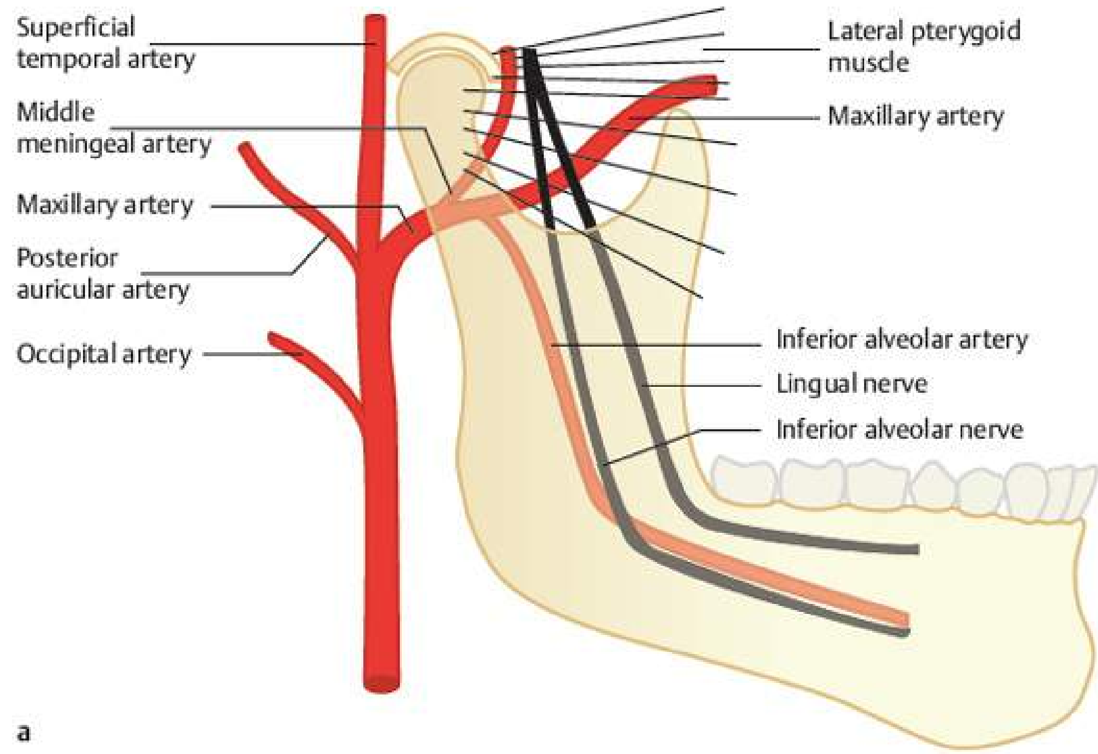
43 Maxillary Artery

F. Goetz, A. Giesemann

The course of the maxillary artery has often been related to the lateral pterygoid muscle and the mandibular nerve branches. In addition to the variants shown here, both division of the maxillary artery and piercing of the muscle are rare findings.[1–13]

Pathologic conditions involving branches of the maxillary artery can be diverse. Variants and anastomoses need to be considered, especially when endovascular treatment is used.[14]

43.1 Course Lateral to the Lateral Pterygoid Muscle (66%)



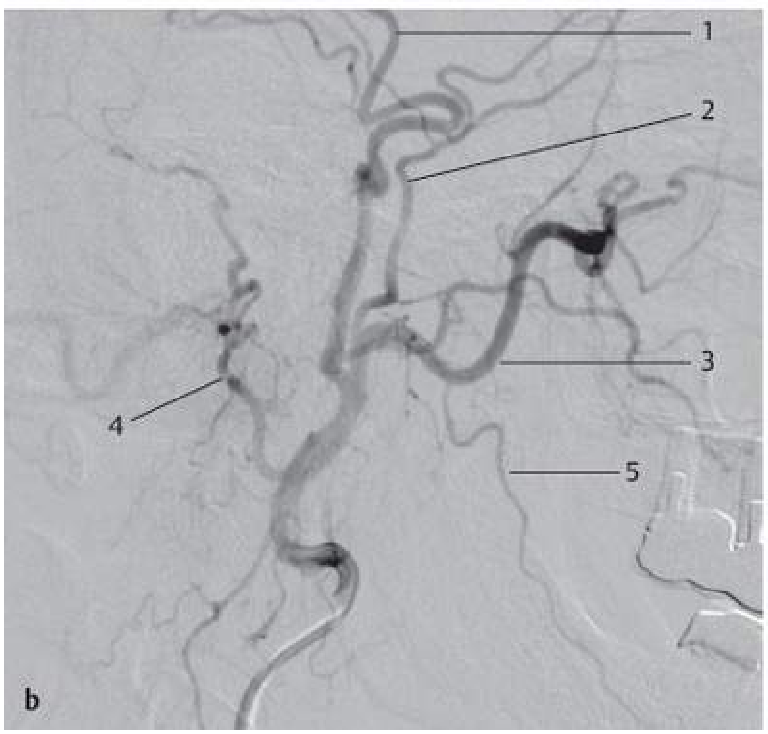


Fig. 43.1 Middle meningeal artery originates proximally to the inferior alveolar artery (60%). Schematic (**a**) and X-ray angiography,

lateral projection, proximal external carotid artery injection (**b**). **1** Superficial temporal artery; **2** middle meningeal artery; **3** maxillary artery; **4** posterior auricular artery; **5** inferior alveolar artery.

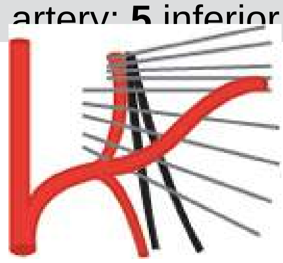


Fig. 43.2 Middle meningeal artery originates opposite the inferior alveolar artery (3%). Schematic.

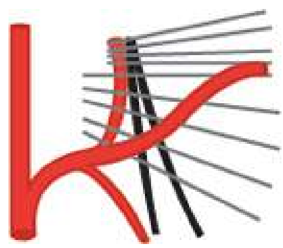


Fig. 43.3 Middle meningeal artery originates distally to the inferior alveolar artery (3%). Schematic.

43.2 Course Medial to the Lateral Pterygoid Muscle and Lateral to the Main Branches of the Mandibular Nerve (21%)

Fig. 43.4 Middle meningeal artery originates proximally to the inferior alveolar artery (2%). Schematic.

Fig. 43.5 Middle meningeal artery originates opposite to the inferior alveolar artery (1%). Schematic.

Fig. 43.6 Middle meningeal artery originates distally to the inferior alveolar artery (18%). Schematic.

43.3 Course Medial to the Lateral Pterygoid Muscle and Medial to or between the Main Branches of the Mandibular Nerve (13%)

Fig. 43.7 Maxillary artery is medial to the lingual and inferior alveolar nerves (middle meningeal artery is always distal to the inferior alveolar artery) (6%). Schematic.

Fig. 43.8 Maxillary artery runs between the lingual and inferior alveolar nerves (3%). Schematic.

Fig. 43.9 Maxillary artery runs through a loop in the inferior alveolar nerve (4%). Schematic.

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44 Development of the Arteries of the Head

F. Goetz, A. Giesemann

The arteries of the head derive from branchial arteries (I–IV), the early development of which is described in Chapter 1. The cervical segmental arteries (see **Fig. 44.1**, C1–C6) form an anastomotic chain which later becomes the vertebral artery (see **Fig. 44.3; **cervical and cerebral vertebral arteries). The corresponding "segmental arteries" of the head (see **Fig. 44.1**; proatlantal, trigeminal, otic, and hypoglossic artery) are connected with the terminal branch of the internal carotid artery, the cerebral vertebral artery, which bends in a posterior and caudal direction.

The cervical and cerebral vertebral arteries form one continuous artery on each side and the segmental arteries disappear (**Fig. 44.2** and **Fig. 44.3**). Between the trigeminal and hypoglossic artery, the initially paired vertebral arteries merge to form the basilar artery.

At an early stage, a large area of the face is supplied by a branch of the second branchial artery (**Fig. 44.2**), the stapedial artery. Its name derives from the stapes of the middle ear which forms around this artery. The three main branches of the stapedial artery join the three branches of the trigeminal nerve, and the supraorbital, infraorbital, and mandibular arteries. Later (**Fig. 44.3**) two anastomoses are formed, one between the maxillary artery from the external carotid artery and the mandibular artery, and the other between the ophthalmic and the supraorbital arteries. The stapedial artery atrophies, and the maxillary artery supplies almost the whole area of the primitive stapedial artery. Only the supraorbital artery remains connected to the ophthalmic artery.

The anomalies shown in Chapter 43 for the maxillary artery can be explained by the embryological development. The original anastomosis between the stapedial and external carotid arteries is medial to the mandibular nerve. As a rule, a second anastomosis is formed lateral to the lateral pterygoid muscle and the first anastomosis disappears.[1–12]

44.1 Persistent Stapedial Artery (<0.1%)

A persistent stapedial artery is a rare anomaly. This artery originates from the extracranial part of the internal carotid artery, enters the skull medial to the styloid process, runs to the middle ear in an osseous canal, is surrounded by the stapes, and reaches the middle cerebral fossa in front of the canal of the major petrosal nerve and ends as a middle meningeal artery (see also **Fig. 44.2**).[13–19]

Cross-sectional imaging findings of a persistent stapedial artery are (1) a linear structure crossing the middle ear over the promontory; (2) an enlarged facial nerve canal or a separate canal parallel to the facial nerve; and (3) absence of the foramen spinosum.[20]

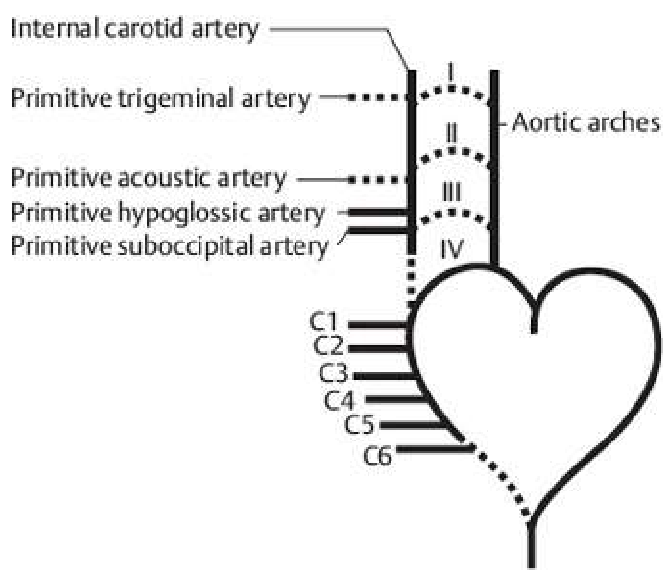

Fig. 44.1 Early development of the arteries of the head which derive from the branchial arteries. Longitudinal anastomosis of the segmental arteries (C1–C6) forms the vertebral artery. I–IV, branchial arteries.

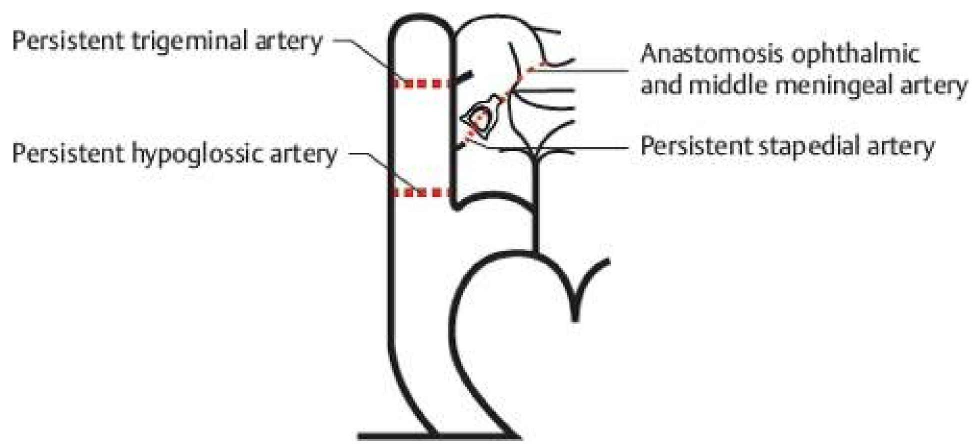

Fig. 44.2 Persistent trigeminal and hypoglossic arteries. At an early stage, the stapedial artery forms anastomoses to the ophthalmic and middle meningeal arteries.

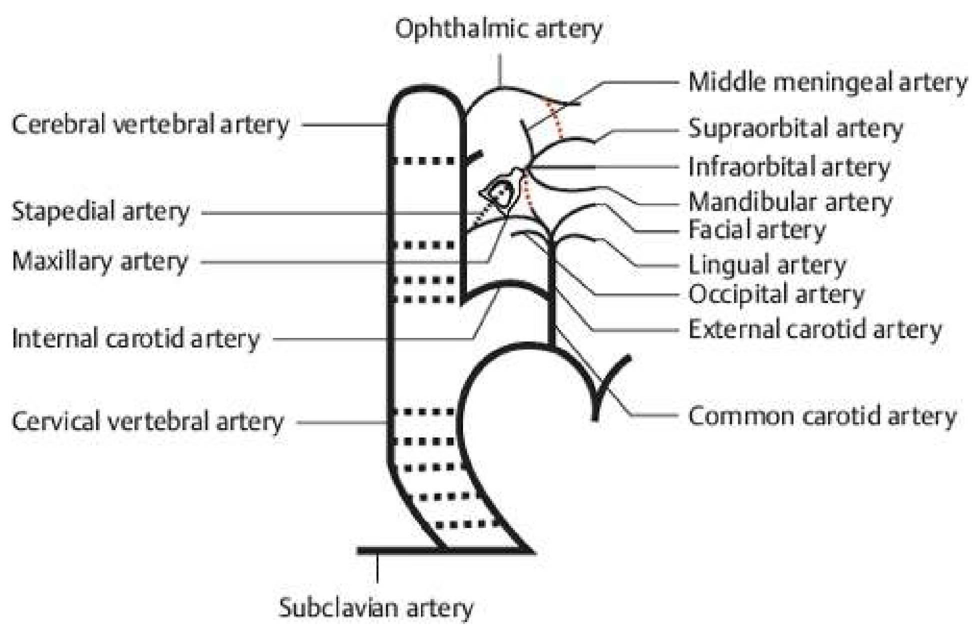

Fig. 44.3 Later, additional anastomoses (dashed red lines) are formed.

44.2 Anastomoses between Internal Carotid and Basilar Artery

44.2.1 Trigeminal Artery (<0.1%)

The trigeminal artery branches from the intracranial internal carotid artery within the cavernous sinus, pierces the dorsum sellae frequently and reaches the rostral parts of the basilar artery. It is 2 to 3 cm long (**Fig. 44.4**). The increased performance of angiographies of cerebral arteries has resulted in the more frequent description of this anomaly.[11,21–31]

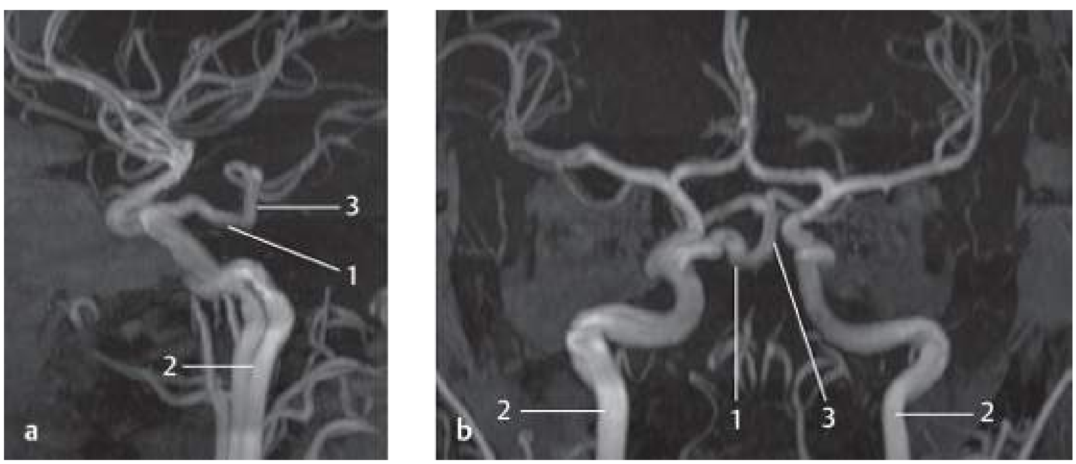

Fig. 44.4 Trigeminal artery (<0.1%). 3D time-of-flight MRA, lateral (**a**) and anterior (**b**) **MIPs. 1** Trigeminal artery; **2** internal carotid artery; **3** basilar artery.

44.2.2 Hypoglossic Artery (Very Rare)

The persistent hypoglossic artery has been described less frequently than the trigeminal artery. This vessel originates from the extracranial part of the internal carotid artery, enters the skull via the hypoglossic canal, and ends in the caudal part of the basilar artery instead of a vertebral artery.[28,32–40]

44.2.3 Proatlantal Artery (Very Rare)

This artery is comparable to the hypoglossic artery, but it runs between the atlas and occipital bone and enters the skull via the great foramen. This vessel has also been named the primitive suboccipital artery.[32,41–45]

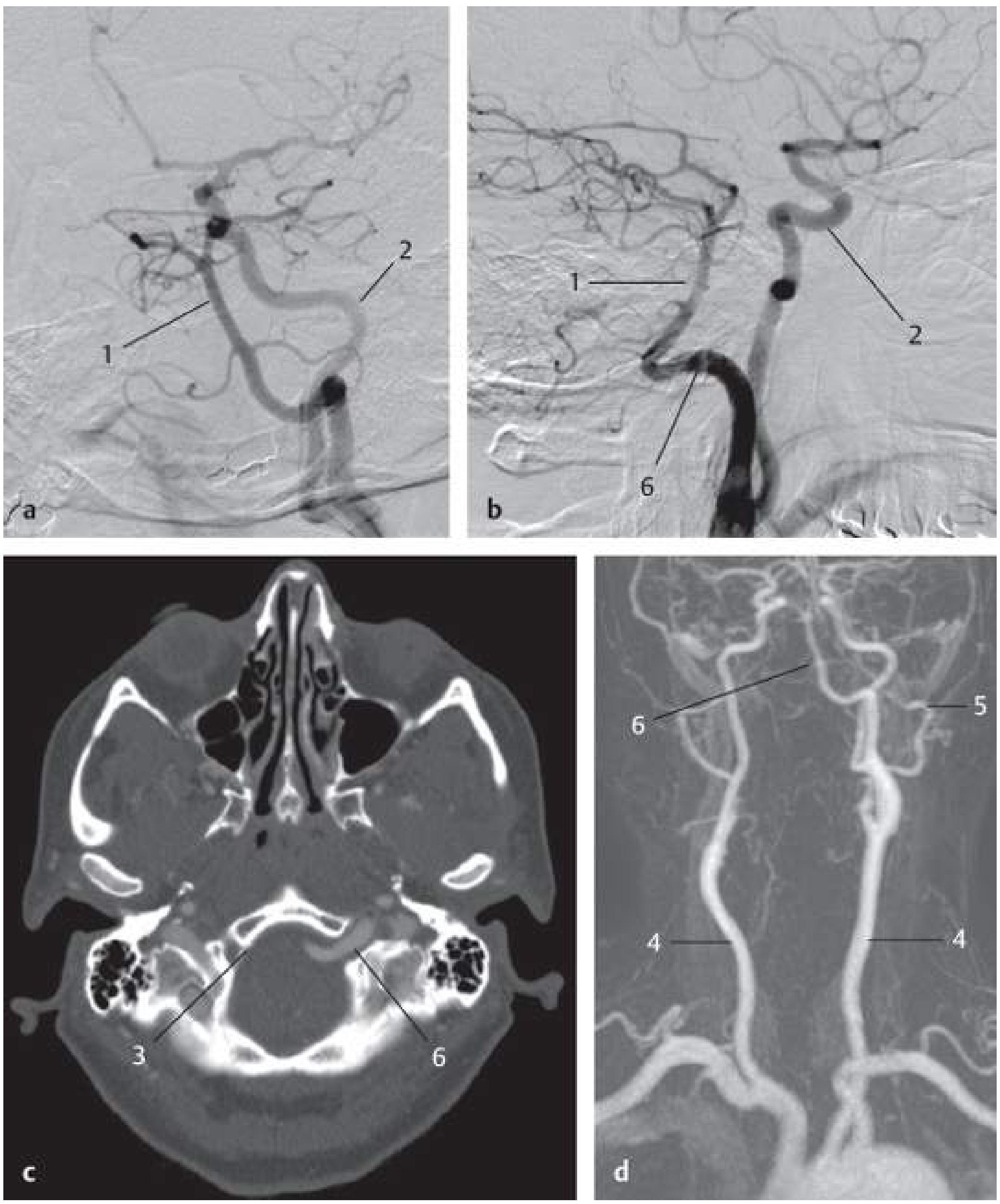

Fig. 44.5 Persistent hypoglossic artery. DSA, oblique view (a) and lateral oblique view (b); CTA at the level of the hypoglossic foramen (c); and contrast-enhanced MRA (d). 1 Basilar artery; 2 internal carotid artery; 3 foramen of the right hypoglossic nerve; 4 common carotid artery; 5 occipital artery; 6 persistent hypoglossic artery.

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45 Ophthalmic Artery

F. Goetz, A. Giesemann

The practical importance of an anastomosis between the ophthalmic and middle meningeal artery is that branches of the external and internal carotid artery anastomose. The frequency of the origin of the middle meningeal artery from the ophthalmic artery seems to reflect racial differences, for instance, in skulls of people from Papua the foramen spinosum is absent in approximately 10%.[1–4]

45.1 Connections between the Ophthalmic and Middle Meningeal Arteries

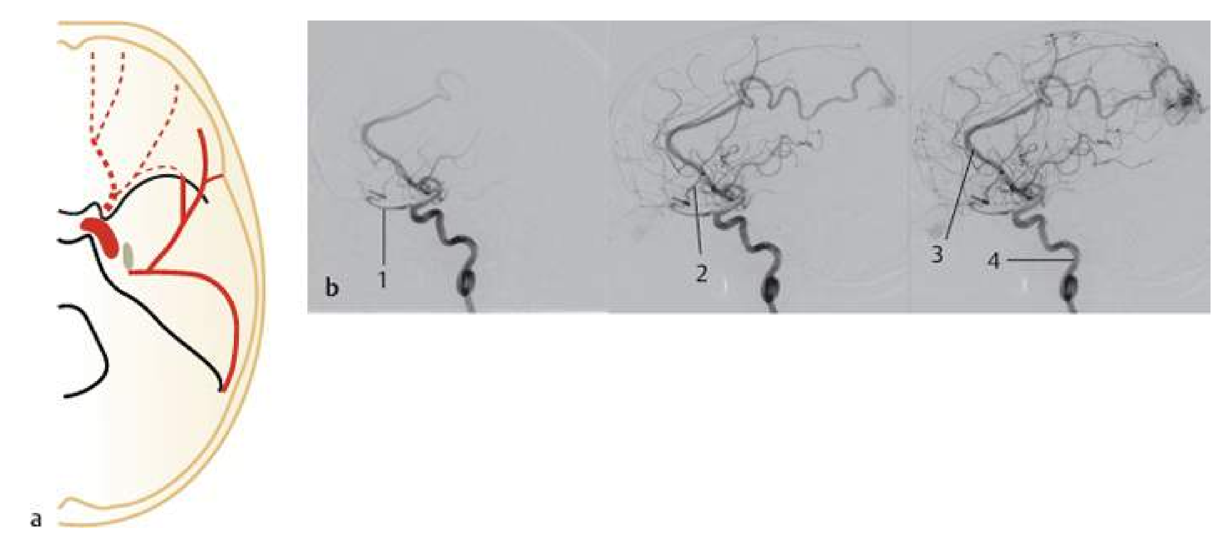

Fig. 45.1 “Normal” situation: only a minor anastomosis between the ophthalmic and middle meningeal arteries (96%). Schematic (a) and X-ray angiography (b), lateral view, three frames after internal carotid artery injection. The middle meningeal artery in b originates from the ophthalmic artery; the patient has an occipital

arteriovenous malformation. 1 Ophthalmic artery; 2 middle meningeal artery; 3 anterior cerebral artery; 4 internal carotid artery.

Fig. 45.2 Large anastomosis: the ophthalmic artery originates with comparably strong roots from the internal carotid and middle meningeal arteries (<1%). Schematic.

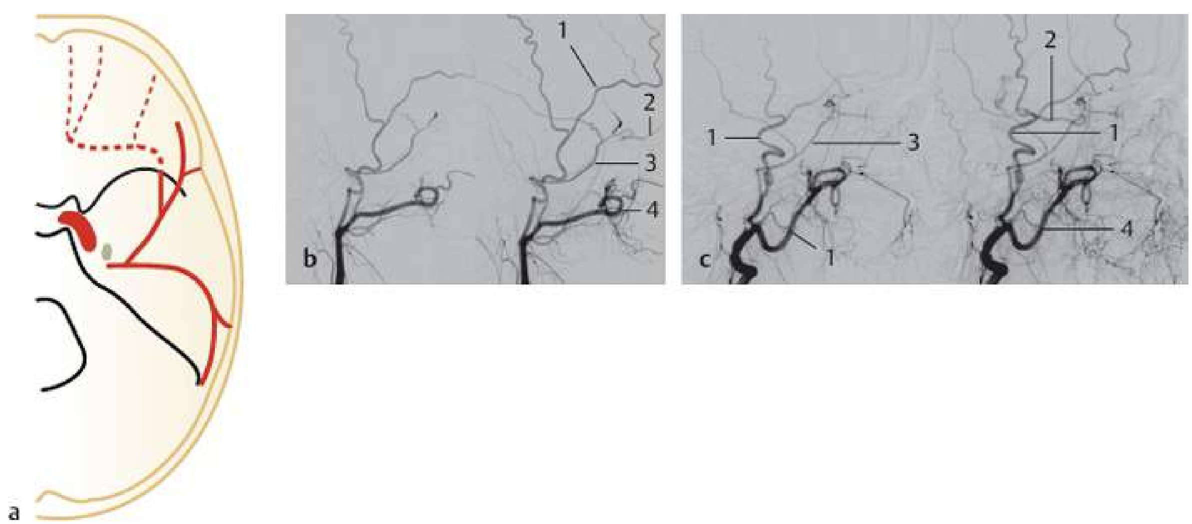

Fig. 45.3 The ophthalmic artery is a branch of the middle meningeal artery (<0.1%). Schematic (a) and X-ray angiography

(**b,c**), **lateral view, two frames after distal external carotid artery injection. Note delayed filling of the ophthalmic artery via a tiny anastomotic channel in b and via an anastomotic network in c. 1 Superficial temporal artery; 2 ophthalmic artery; 3 middle meningeal artery; 4 maxillary artery**.

Fig. 45.4 The lacrimal artery is a branch of the middle meningeal artery (1%). Schematic.

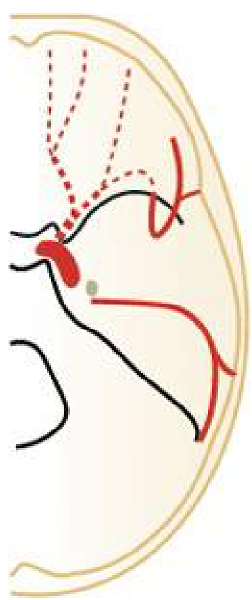

Fig. 45.5 The anterior branch of the middle meningeal artery originates from the ophthalmic artery (1%). Schematic.

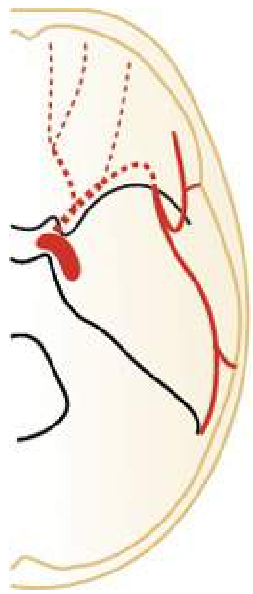

Fig. 45.6 The middle meningeal artery derives from the ophthalmic artery; the foramen spinosum is absent (1%). Schematic.

45.2 Position of the Ophthalmic Artery Relative to the Optic Nerve

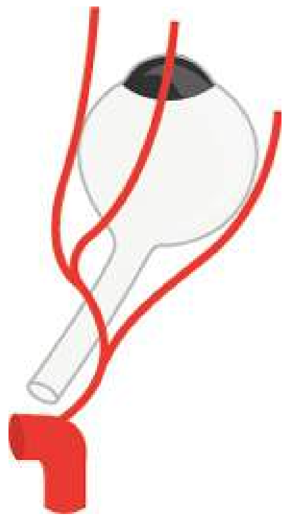

Fig. 45.7 The ophthalmic artery crosses over the optic nerve (90%). Schematic.

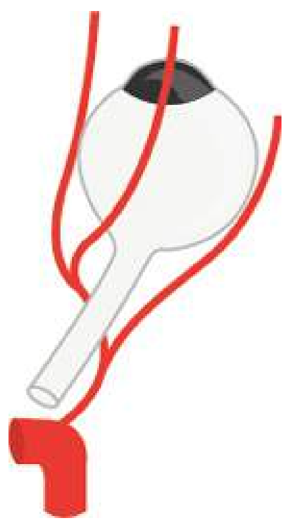

Fig. 45.8 The ophthalmic artery crosses under the optic nerve (10%). Schematic.

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46 Cerebral Arterial Circle (Circle of Willis)

F. Goetz, A. Giesemann

There are many anomalies of the arteries at the base of the skull.[1–7] Some studies deal with anomalies of the internal carotid artery[8–13] and others with the circle of Willis[14–26] or its branches as the middle cerebral artery[27–30] or cerebellar arteries.[31,32] For didactic reasons, the anomalies of the anterior area,[19,33–36] posterior area,[19,37–39] and the basilar artery[40] are depicted separately. These anomalies can be combined in different individuals and result in many different types. The frequencies given here are a compromise between radiological and anatomical studies. Vessels were termed “small” or “absent” (e.g., **Fig. 46.13**) when only negligible collateral circulation took place via such a route.

The recognition of cerebral variants is important as some of these variants might turn pathological in a surgical setting and can influence pathological changes such as brain infarcts and aneurysms.[7]

46.1 Anterior Part of the Cerebral Circle

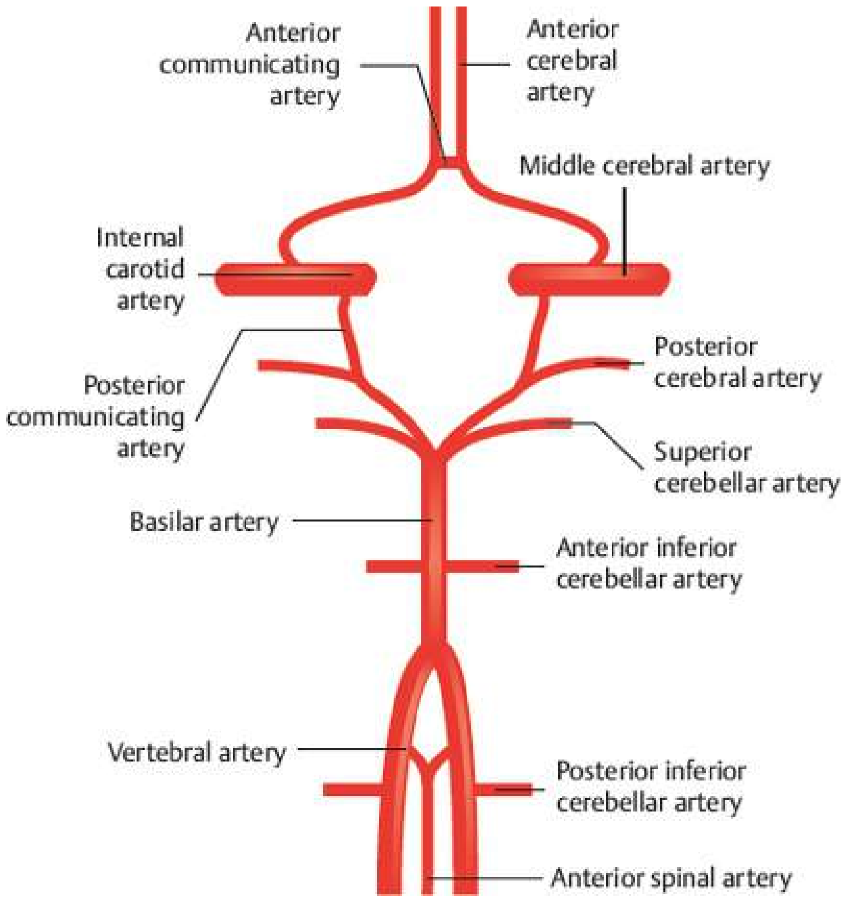

Fig. 46.1 Circle of Willis. Schematic with indication of arteries.

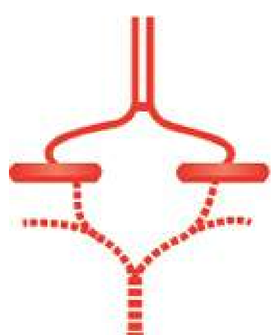

Fig. 46.2 "Normal" situation (60%). Schematic.

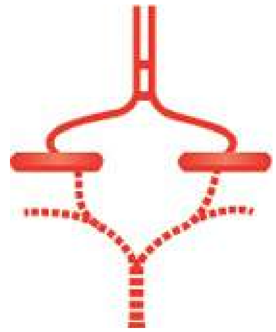

Fig. 46.3 Two anterior communicating arteries (10%).

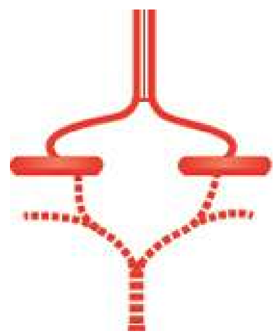

Fig. 46.4 The median artery of the corpus callosum originates from the anterior communicating artery (10%). Schematic.

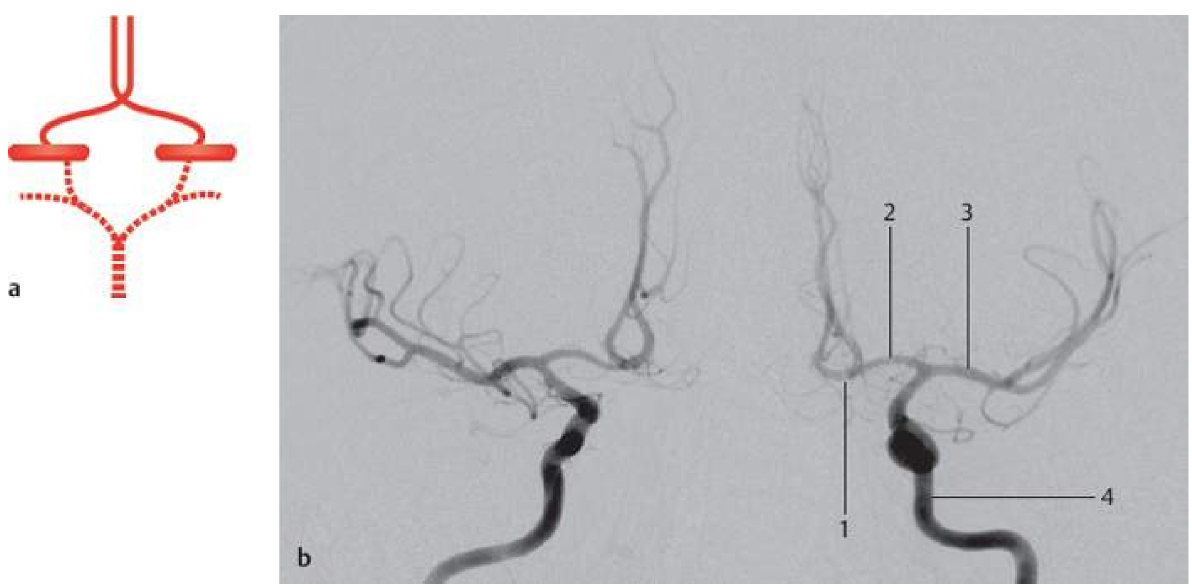

Fig. 46.5 Instead of the anterior communicating artery, a lateral

anastomosis between the two anterior cerebral arteries is present (3%). Schematic (**a**) and X-ray angiography, anterior view of the right and left internal carotid artery (**b**). **1** Anterior communicating artery; **2** anterior cerebral artery; **3** middle cerebral artery; **4** internal carotid artery.

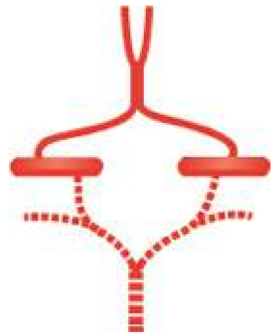

Fig. 46.6 Both anterior cerebral arteries combine partly in a common trunk (5%). Schematic.

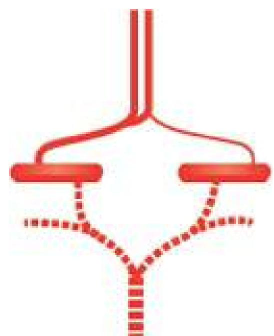

Fig. 46.7 Both anterior cerebral arteries originate from one internal carotid artery (10%). Schematic.

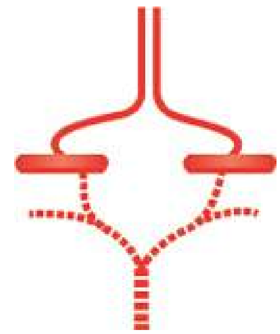

Fig. 46.8 Absence of the anterior communicating artery (1%). Schematic.

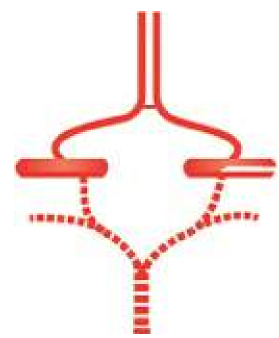

Fig. 46.9 Accessory middle cerebral artery (1%). Schematic.

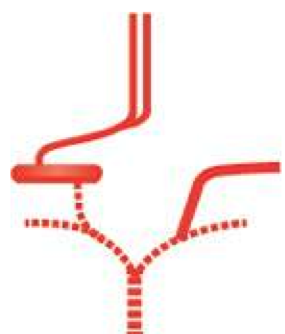

Fig. 46.10 Absence of one internal carotid artery; the middle cerebral artery originates from the basilar artery (0.1%). Schematic.

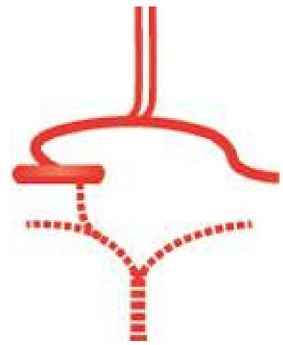

Fig. 46.11 Absence of one internal carotid artery; the middle cerebral artery originates from the other internal carotid artery (0.1%). Schematic.

46.2 Posterior Part of the Cerebral Circle

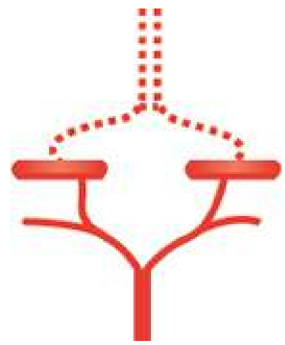

Fig. 46.12 “Normal situation (55%). Schematic.

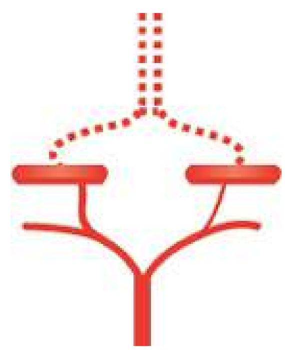

Fig. 46.13 The posterior communicating artery is absent or very small on one side (10%). Schematic.

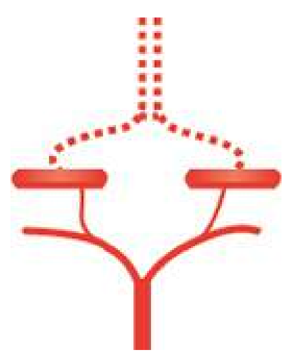

Fig. 46.14 The posterior communicating artery is absent or very

small on both sides (<1%). Schematic.

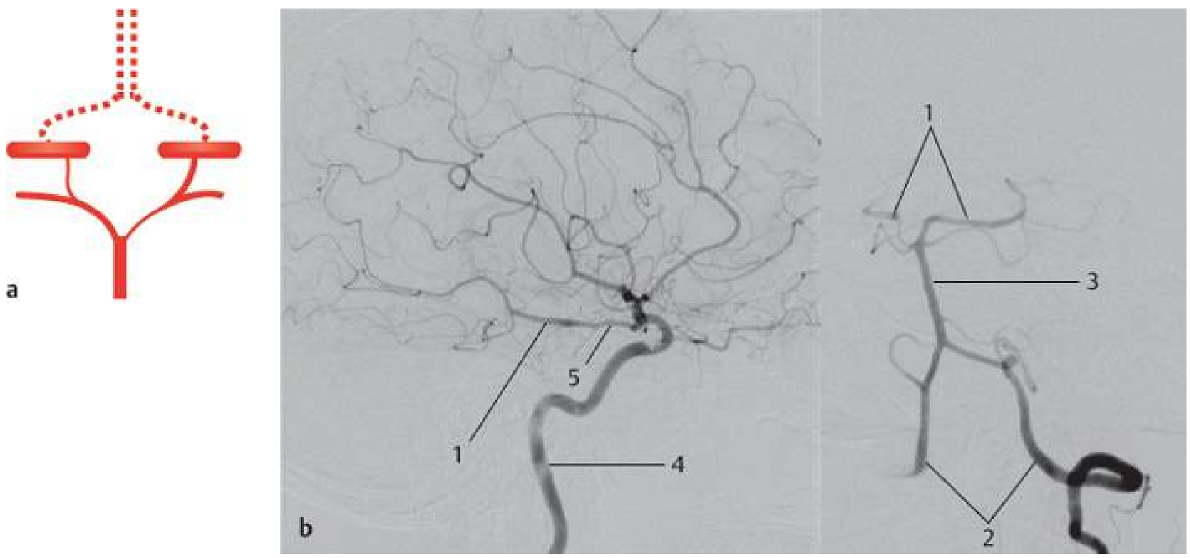

Fig. 46.15 On one side the posterior cerebral artery originates from the internal carotid artery (<1%). Schematic (a) **and X-ray angiography, right internal carotid artery injection, lateral view with a dominant posterior communicating artery and anterior view of the left vertebral artery; not hypoplasia of the so-called P1-segment of the right posterior cerebral artery** (b). **1 Posterior cerebral artery (P2 segment); 2 vertebral artery; 3 basilar artery; 4 right internal carotid artery; 5 posterior communicating artery.**

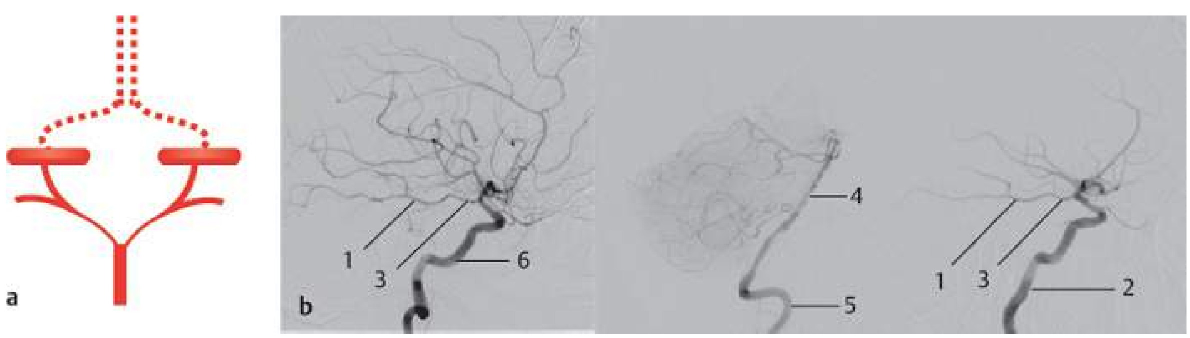

Fig. 46.16 On both sides the posterior cerebral artery originates from the internal carotid artery (<1%). Schematic (a) **and X-ray angiography, lateral views of the left internal carotid artery, left vertebral artery, and right internal carotid artery; left (non-**

dominant) and right posterior communicating arteries and hypoplasia of the P1-segments of both posterior cerebral arteries (faint visibility of both posterior cerebral arteries during vertebral artery injection) (**b**). **1 Posterior cerebral artery; 2 right internal carotid artery; posterior communicating artery; 4 basilar artery; 5 vertebral artery**.

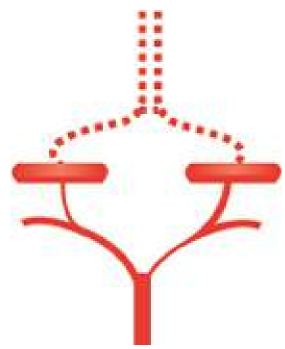

Fig. 46.17 On one side the posterior communicating artery is absent, on the other side the posterior cerebral artery comes from the internal carotid artery (<0.1%). Schematic.

46.3 Basilar Artery

Fig. 46.18 "Normal" situation (88%). Schematic.

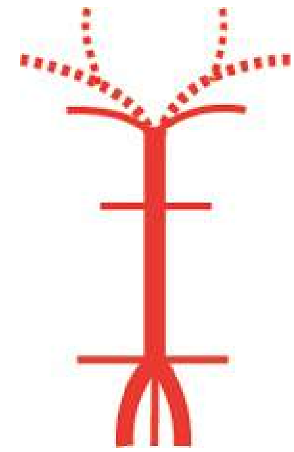

Fig. 46.19 Both vertebral arteries unite in an extremely caudal position (10%). Schematic.

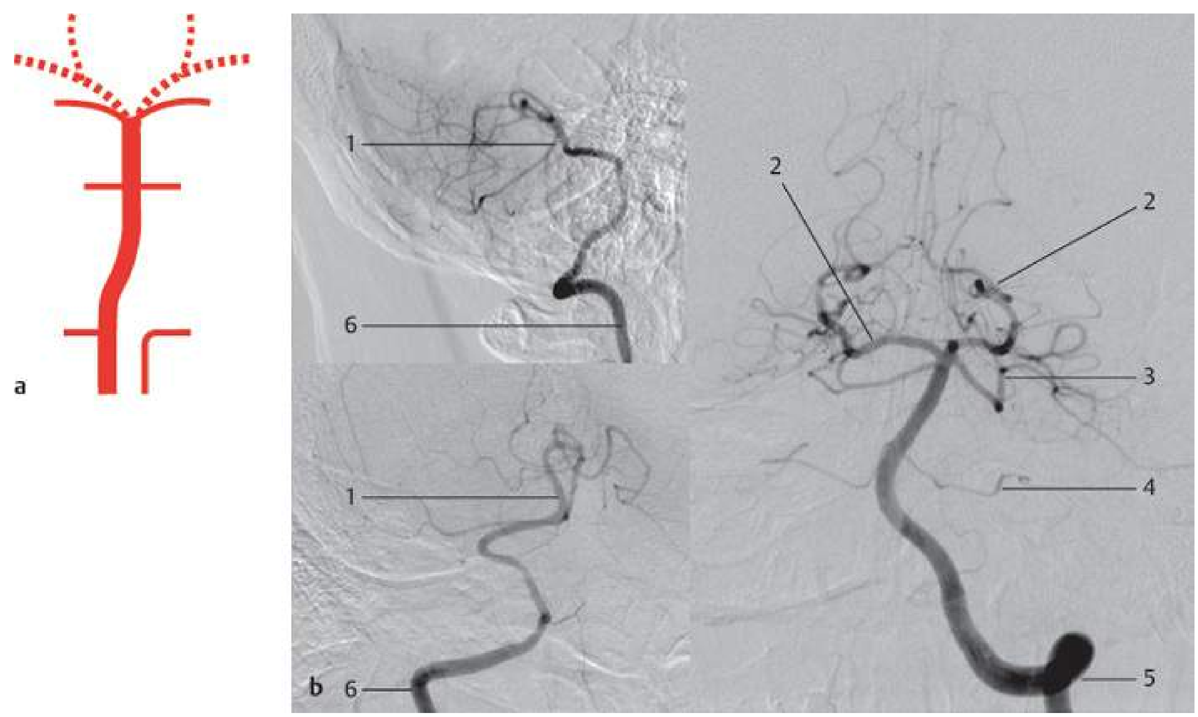

Fig. 46.20 The basilar artery is the continuation of only one vertebral artery, the other vertebral artery ends as the posterior inferior cerebellar artery in most cases (<1%). Schematic (**a**) and X-ray angiography (three frames) (**b**): right vertebral artery injection lateral and anterior view (so-called PICA-ending vertebral artery); anterior view of the left vertebral artery, which is continuous with the basilar artery. **1** Right posterior inferior cerebellar artery (PICA); **2**

posterior cerebral artery (left and right); **3** superior cerebellar artery; **4** anterior inferior cerebellar artery (AICA); **5** left vertebral artery; **6** right vertebral artery.

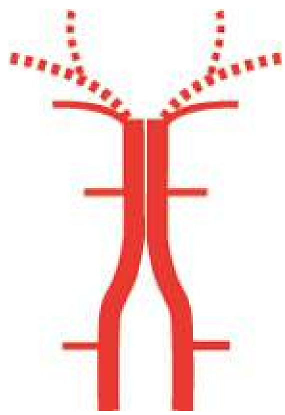

Fig. 46.21 Two basilar arteries, but otherwise normal branches (<1%). Schematic.

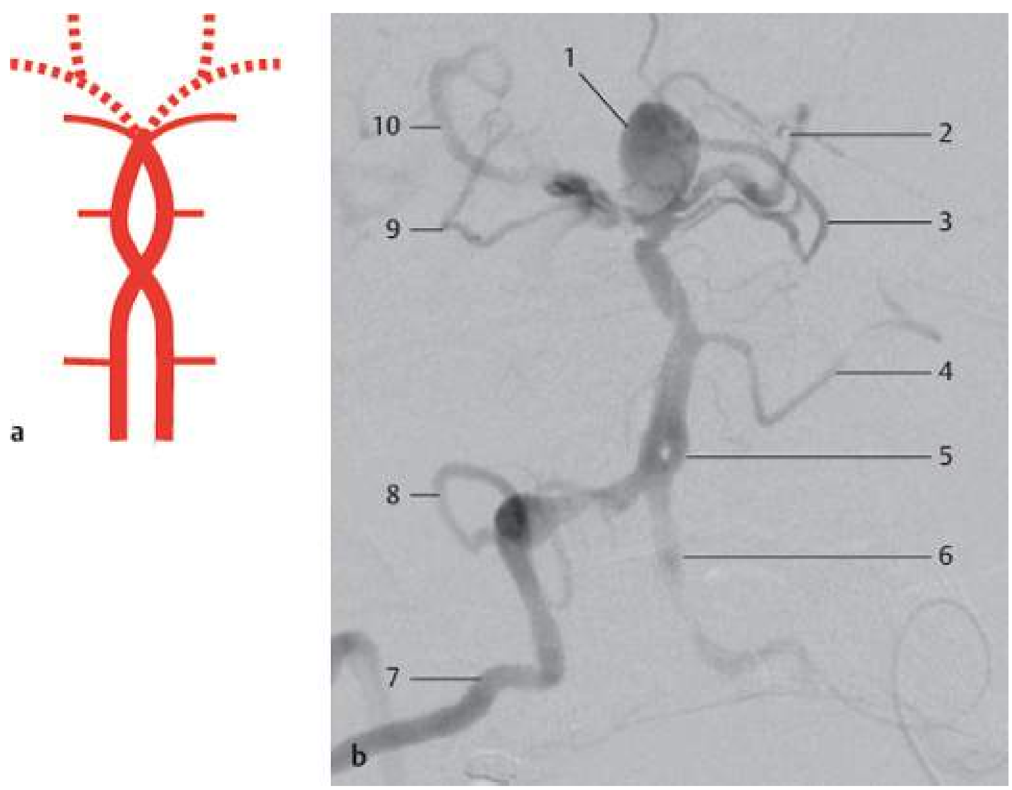

Fig. 46.22 “Island formation” of the basilar artery (<1%). Schematic

(**a**) and X-ray angiography, right vertebral artery injection, anterior view, in a case with a basilar tip aneurysm (**b**).**1** Aneurysm of the basilar tip; **2** left posterior cerebral artery; **3** left superior cerebellar artery; **4** left AICA; **5** fenestration of basilar artery; **6** left vertebral artery (with microcatheter); **7** right vertebral artery; **8** right PICA; **9** right superior cerebellar artery; **10** right posterior cerebral artery.

Fig. 46.23 An anastomosing network instead of a basilar artery (<0.1%). Schematic.

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47 Arteries of the Spinal Cord

F. Goetz, A. Giesemann

The spinal cord is supplied by three longitudinal arterial trunks—the anterior spinal artery and the two posterolateral trunks. The anterior spinal artery is formed by two roots from the vertebral arteries, and anterior radicular arteries reinforce the longitudinal channel at various levels; in the cervical part the anterior radicular arteries arise from the vertebral artery, thyrocervical trunk, and costocervical trunk. Branches from intercostal and lumbar arteries join the longitudinal system at the thoracic and lumbar segments. At the conus terminalis, a periconal anastomotic circle is present connecting anterior spinal with posterior spinal arteries. Usually one artery is larger than the other, that is, the great anterior medullary artery (artery of Adamkiewicz radicularis magna), which is more often found on the left than on the right side and usually between the levels T9 and L2. Variations of the posterior radicular arteries are not shown in **Fig. 47.1**. The great variability in the number of radicular arteries, the prevalence of the left side in the thoracic and lumbar parts and the level of the radicular arteries has been explained by the embryological segmental blood supply and the preferential left side, by the more direct blood flow from the aorta to the left radicular arteries.[1] Paraplegia following orthopaedic surgery of the spine or operation of the aorta stresses the clinical relevance of the anomalies of the spinal cord blood supply.[1–16]

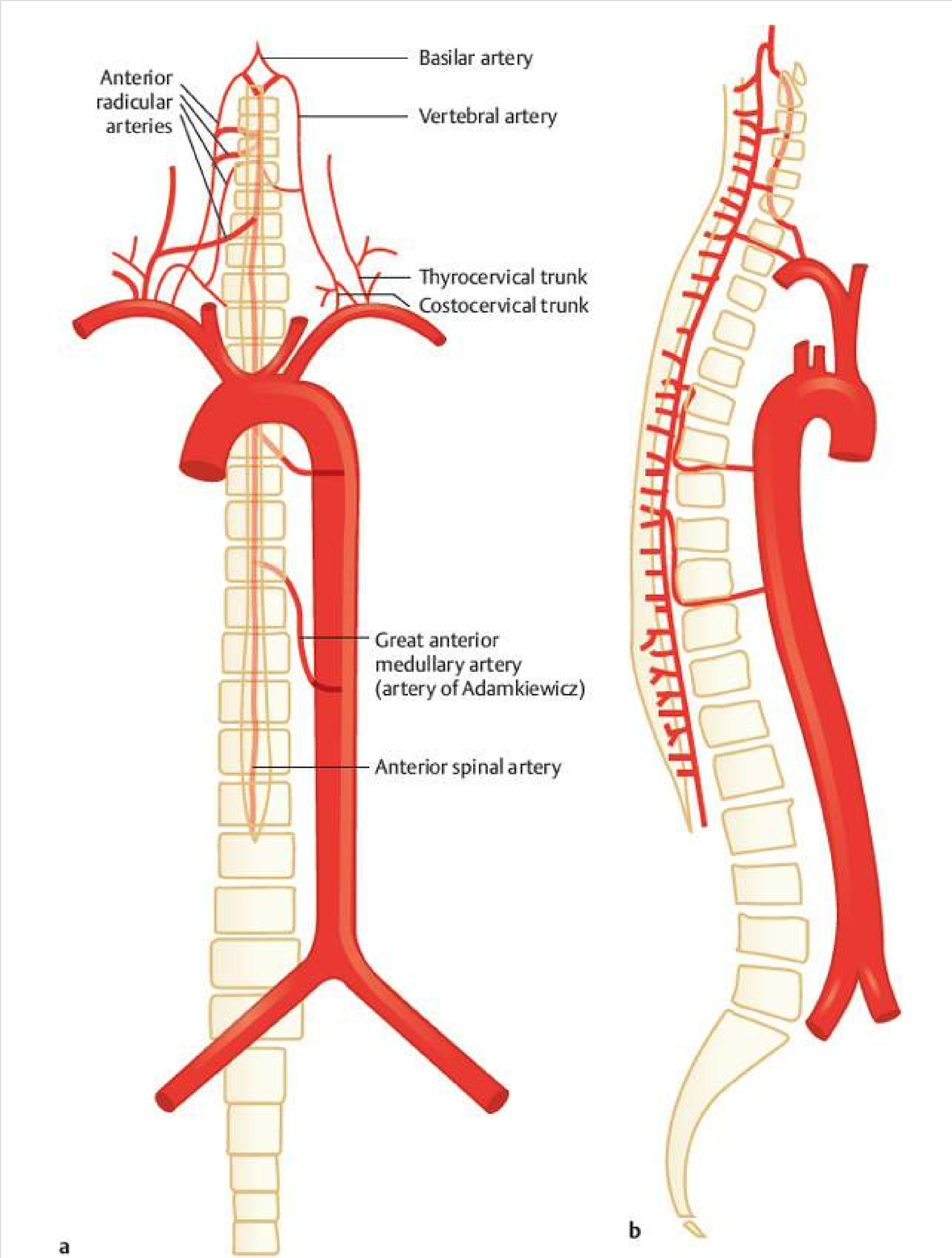

Fig. 47.1 Typical origin of the anterior radicular arteries.

Schematic, anterior (**a**) and lateral (**b**) view.

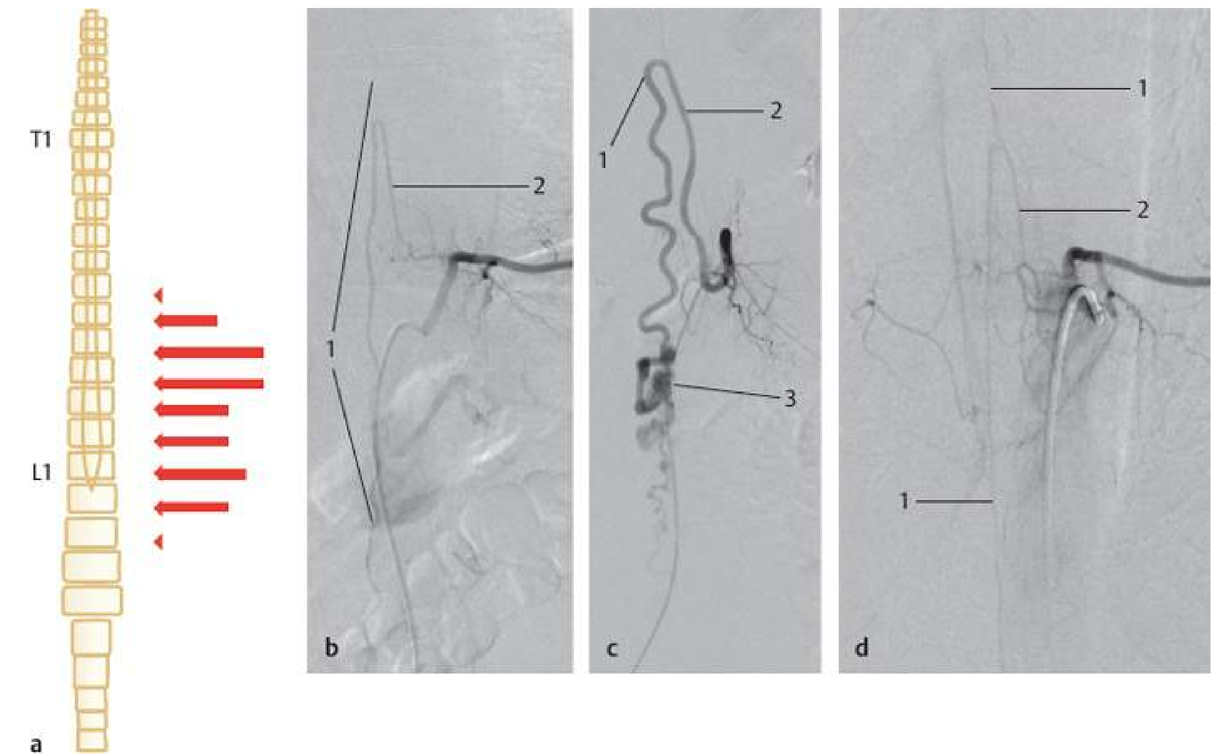

Fig. 47.2 Variable origin of the great anterior medullary artery (artery of Adamkiewicz). Schematic, anterior view (**a**), and X-ray angiography, anterior view, selective injection of radicular arteries (**b–d**). Artery of Adamkiewicz fed from T9 left (**b**), from T10 left in a case with a perimedullary arteriovenous malformation (**c**), and from L1 left (**d**). **1** Anterior spinal artery; **2** artery of Adamkiewicz; **3** perimedullary arteriovenous malformation. T1, first thoracic vertebra; L1, first lumbar vertebra.

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Index

Note: The terms *arteria* and *artery* are always omitted.

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D

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F

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H

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M

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O

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R

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