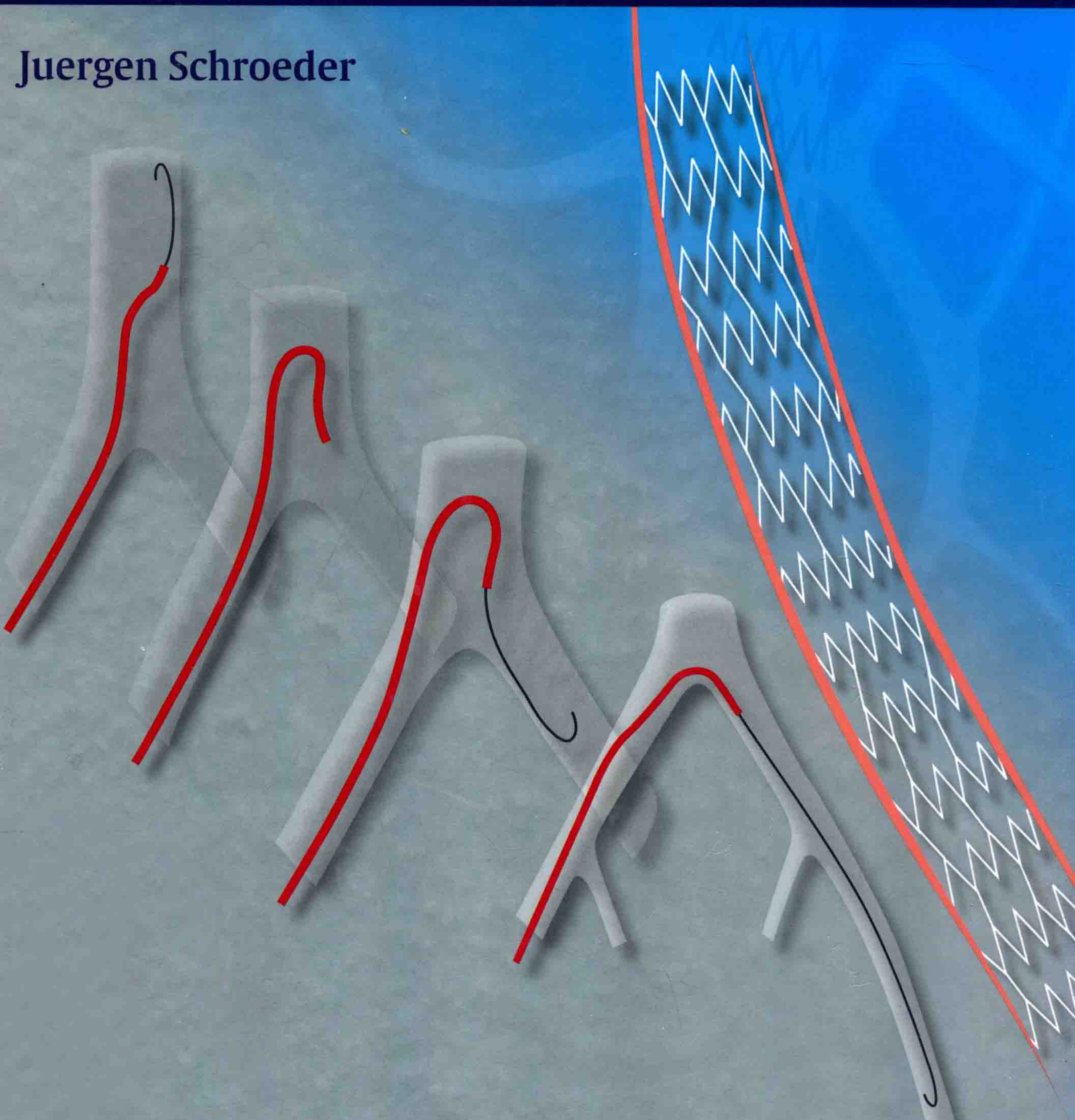
Peripheral Vascular Interventions: An Illustrated Manual

Juergen Schroeder



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Peripheral Vascular Interventions: An Illustrated Manual

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573 Illustrations

Thieme
New York • Stuttgart

Library of Congress Cataloging-in-Publication Data

Schröder, Jürgen, 1938-
[Trainer vaskuläre Interventionen. English]
Peripheral vascular interventions : an illustrated manual / Jörgen Schröder.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-3-13-169751-6
I. Title.
[DNLM: 1. Peripheral Vascular Diseases--surgery. 2. Radiography, Interventional--methods. WG 500]

616.1'31--dc23

2012046150

This book is an authorized translation and update of the 1st German edition published and copyrighted 2011 by Georg Thieme Verlag, Stuttgart, Germany. Title of the German edition: Trainer Vaskuläre Interventionen.

Translator: John Grossman, Schrepkow, Germany

llustrator: Jürgen Schröder, Fockbek, Germany and Malgorzata & Piotr Gusta, Paris, France

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Rüdigerstrasse 14, 70469 Stuttgart, Germany
http://www.thieme.de
Thieme New York, 333 Seventh Avenue,
New York, NY 10001, USA
http://www.thieme.com

Cover design: Thieme Publishing Group
Typesetting by Maryland Composition, USA
Printed in Germany by Stürtz GmbH, Würzburg

ISBN 978-3-13-169751-6
eISBN 978-3-13-169761-5

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Preface

It has been a mere 48 years since the first intervention in a pelvic artery - an incidental observation yet one that Charles Dotter pursued systematically and enthusiastically. This has since given rise to a major specialty that now boasts its own congresses, journals, and thousand-page textbooks. Scholars in this field will naturally be more interested in the broad and rapid increase in new scientific knowledge than in the description of the fundamentals, which have changed little since Dotter's time.

Vascular interventions have evolved from the technique of angiography. As recently as 20 years ago, every beginner in diagnostic angiography had ample opportunity to learn how to work with guidewire and catheter. Many of today's diagnostic studies require contrast but dispense with the catheter. At the same time, shrinking budgets for medical staff have made it far less common to find an experienced practitioner side by side with a beginner at the angiography table. Many of the details that were once conveyed in such a teacher-student relationship are difficult to present clearly in text alone, nor can they be demonstrated on standard angiographic images.

Abstract description will always be a roundabout way for imparting practical instructions for procedures performed primarily under visual control. The emphasis must be on visual representation. Since there is an obvious shortage in this respect, I have combined concise texts with numerous schematic diagrams in an attempt to illustrate what one needs to perform vascular interventions successfully.

This little book is hardly intended to replace one of the customary textbooks. Moreover, I have purposely omitted detailed descriptions of certain complex, high-risk interventions such as endovascular aortic prostheses or carotid artery stents. Whoever intends to attempt such procedures should no longer need this book.

There are some firm rules in interventional radiology that one may not disregard without endangering the patient. Yet many other precepts that are also accepted as rules are actually better described as conventions. Some originate from such simple considerations as the limited time available for performing the intervention. This does not mean that such rules should not become established. On the contrary, only the observance of rules generally accepted as binding can provide a basis for optimizing procedures according to empirical criteria. From this it also follows that such rules must continually be reexamined in the interest of further developing the methods.

You will occasionally find an instruction in this book that deviates from the customary recommendations. A review of the current literature will reveal that this is hardly unusual. Yet every such deviation must be based on logical reasoning and supported by one's own experience.

The allurement of interventional radiology is that it can often achieve maximum successes with minimal procedures. Its actual therapeutic tools are almost always simple. Interventional radiology is not magic. Its successes are largely the result of meticulous planning. And the fast interventionalist is one who understands how to reach their goal directly.

Winter 2012 *Jürgen Schröder*

Acknowledgments

I feel very grateful for many people. Above all to my wife Elisabeth and our children Hannah, Robert, and Ruth.

Walter Frommhold, Charles Dotter, and Josef Rösch were important teachers. Since the beginnings of interventional radiology, many have accompanied me in Tübingen, Heidelberg, Rendsburg, and Flensburg. I have learned from them and with them, and have acquired and evaluated experience together with them. I would expressly like to mention Gernot Bürkle, Ulrich Mittmann, Burckhard Terwey, Jens Allenberg, Christos Papachrysanthou, Bernd Glücklich, Issifi Djibey, Walter Müller, Ulrich Schroeder, Stefan Müller-Hülsbeck, Lothar Wöstenberg, Hedwig Horn, Klaus Graeber, Gudrun Petersen, Mathias Ehmke, Van Khiem Tran, and Karsten Schmidt.

I owe so very much to my mother Josefine Gieshoff who died at a young age. One gift of hers was the joy of drawing.

Glossary

"Glide" wire	Nitinol wire with hydrophilic coating
Ipsilateral	On the same side as the vascular access
Contralateral	On the opposite side
Overlay	Fluoroscopic image over an angiographic image
Primary patency rate	Percentage of patent vessels after one treatment
Roadmapping	Digital subtraction fluoroscopy
Secondary patency rate	Patency rate after the second or third intervention
Y prosthesis	Aortobifemoral or aortobiiliac bypass

Abbreviations

A.	Artery
Aa.	Arteries
ABI	Ankle brachial index
ACC	Acetylcysteine
ACE	Angiotensin converting enzyme
ADP	Adenosine diphosphate
ATA	Anterior tibial artery
AV fistula	Arteriovenous fistula
C-arm	C-arm fluoroscopic image intensifier
CFA	Common femoral artery
CFV	Common femoral vein
CIA	Common iliac artery
CLI	Critical limb ischemia
CO_2	Carbon dioxide
CT	Computed tomography
CTA	CT angiography
DES	Drug-eluting stent
DSA	Digital subtraction angiography
EIA	External iliac artery
FMD	Fibromuscular dysplasia
GFR	Glomerular filtration rate
HIT	Heparin-induced thrombocytopenia
IA	Intra-arterial
IIA	Internal iliac artery
IJV	Internal jugular vein
IV	Intravenous
IVC	Inferior vena cava
IU	International units
IM	Intramuscular
LAO	Left anterior oblique
M	Muscle
MRA	Magnetic resonance angiography
MRI	Magnetic resonance imaging
NaCl	Sodium chloride
NFS	Nephrogenic systemic fibrosis
OTW	Over the wire (balloon catheter)
PA	Posteroanterior (projection)
PA	Plasminogen activator
PD	Plantodorsal
PTA	Percutaneous transluminal angioplasty
PTA	Posterior tibial artery
PTFE	Polytetrafluoroethylene
PTT	Partial thromboplastin time
PVA	Polyvinyl alcohol
RA	Renal artery
RAO	Right anterior oblique
RAS	Renal arterial stenosis
RDC	Renal double curve
RH	Rösch Hepatica
r-tPA	Recombinant tissue plasminogen activator
RX	Rapid exchange
SFA	Superficial femoral artery
SVC	Superior vena cava
TIPS	Transjugular intrahepatic portosystemic shunt
TOS	Thoracic outlet syndrome

Contents

1 General

Clinical Presentation of Peripheral Arterial Occlusive Disease

This book describes treatment methods that are used in the vast majority of cases of patients with peripheral arterial occlusive disease. It is not the task of this book to discuss this disease entity in its various manifestations. This chapter is a brief review of what the physician must be aware of when examining and treating a patient with peripheral arterial occlusive disease.

Peripheral arterial occlusive disease is in most cases a degenerative disorder that increases in severity with age and is promoted by various risk factors.

Risk factors:
- Age
- Smoking
- Diabetes
- Hypertension
- Hyperlipidemia
- Sedentary lifestyle

Every invasive therapy must therefore include consultation with the patient about how the further course of the disorder can be favorably influenced by avoiding or reducing these risk factors.

Recommendations:
- Quit smoking
- Reduce weight
- Treat hyperlipidemia
- Control diabetes
- Reduce hypertension
- Acetylsalicylic acid (aspirin)
- Exercise

Quitting smoking and losing weight are probably the most challenging tasks for patients, and most patients must seek professional help.

Hyperlipidemia can be very well controlled with medication in many patients, and treatment is inexpensive. It is interesting to note the result of a study on the effect of perfusion-stimulating medications on walking distance. Cholesterol synthesis inhibitors had the best *long-term effect* (Momsen et al 2009).

Diabetes must be rigorously treated. Hypertension is also usually controllable with medications (and by weight loss as well). Small doses of acetylsalicylic acid have long been recognized as prophylaxis against recurrence and possibly for primary prevention. Clopidogrel may be tried in those patients who do not tolerate aspirin. Finally, those who do not enjoy walking or cycling may consider finding a walking companion, adopting a dog, or joining an athletic club that features a coronary sports group.

Certainly there are few diseases that can be so extensively clarified by a thorough patient history as can early-stage peripheral arterial occlusive disease. The cardinal symptom is intermittent claudication. Typically this manifests itself as lower leg pain or cramps that occur after the patient walks a certain distance and disappear after a rest. Less often such cramps will occur in the thigh or buttocks. In such cases the cause is usually located in the iliac arteries.

Walking distance should be measured on a treadmill. There are numerous noninvasive diagnostic methods. The most important one is measuring systolic blood pressure in all four extremities to determine the ankle-brachial index (ABI), also referred to as the ankle-brachial pressure index (ABPI).

$$\text{ABI} = \frac{\text{Systolic pressure in distal posterior tibial or dorsalis pedis artery}}{\text{Systolic blood pressure in arm}}$$

Where pressure varies between the right and left arms, the higher value serves as reference. The ABI is determined for each leg. Unreasonably high ABI values are not uncommon in patients with diabetes. This is due to sclerosis of the arterial media, which reduces the compressibility of the arteries of the leg regardless of blood pressure.

> Normal values for the ABI lie between 1.1 and 1.0. An ABI < 0.90 at rest is regarded as abnormal; after exercise it can decrease by 15–20%.

This index is particularly suitable for documenting the success of treatment and evaluating the course of the disorder. The findings detected with the ABI become significantly more apparent with exercise (treadmill).

Table 1.1 Staging of peripheral arterial occlusive disease according to Fontaine and Rutherford

Fontaine's classification		Rutherford's classification		
Stage	**Clinical aspects**	**Degree**	**Category**	**Clinical aspects**
I	No symptoms	0	0	Asymptomatic
IIa	Claudication, walking distance > 200 m	I	1	Slight claudication
IIb	Claudication, walking distance < 200 m (moderate to severe claudication)	I	2	Moderate claudication
		I	3	Severe claudication
III	Ischemic pain at rest ("cold leg")	II	4	Ischemic pain at rest
IVa	Trophic changes, minor necrosis, and tissue loss	III	5	Minor tissue loss
IVb	Major tissue loss	III	6	Major tissue loss

The pressure drop along a stenosis is nearly proportional to the flow according to Poiseuille's law. Therefore, when blood flow increases with exercise, the pressure gradient must also increase.

Standardizing therapy and promptly agreeing on treatment options require that peripheral arterial occlusive disease be classified in defined stages (**Table 1.1**).

Staging According to Fontaine and Rutherford

For purposes of everyday clinical practice, Fontaine's classification is sufficient and more practicable:

Stage I: No symptoms = no treatment. Usually it is an incidental finding, for example, occlusion of the superficial femoral artery that is fully compensated for by collaterals of the deep femoral artery.

Stage IIa: Findings are compensated for at rest so that there is no absolute indication for treatment. Indications depend on lifestyle. A maximum walking distance of 200 m would render a postal delivery worker unfit for employment, whereas it hardly represents a significant restriction for an elderly retired person.

Stage IIb: Where the maximum walking distance is < 200 m, one will usually opt for invasive treatment if the anatomical situation so permits.

Stage III: Absolute indication for treatment. The leg is acutely at risk, for example, from thromboembolic occlusion of a major vessel.

Stage IV: Treatment is clearly indicated and depends on the extent of findings, the vascular situation, and comorbidities (very often diabetes mellitus).

Other Clinical Definitions

Critical Limb Ischemia

Critical limb ischemia (*CLI*), a common term, is defined as chronic pain at rest, ulceration, or gangrene secondary to peripheral arterial occlusive disease. It is important to distinguish this from acute ischemia (stage III, see below). CLI is a clinical category but should be corroborated by objective examinations (ulcers on the lower leg are usually caused by venous pathology, foot ulcers by arterial). Revascularization is the best therapy. Systemic antibiotic treatment is indicated in cases of infection.

Acute Ischemia ("Cold Leg"), Stage III

Causes:
- Arterial thrombosis (thrombosed bypass, thrombosed popliteal artery aneurysm)
- Embolism

Clinical symptoms:
- Pain
- Lack of pulse (confirmed by Doppler ultrasonography)
- Pallor
- Paresthesia
- Palsy

Important: Cause must be identified immediately as irreparable damage could otherwise result. Angiography wherever possible. Anticoagulation (heparin).

Treatment options:
- Thrombolysis
- Aspiration thrombectomy

- Surgery (especially with proximal embolisms and in popliteal aneurysm)

Trans-Atlantic Inter-Society Consensus (TASC) II

In 2007, recommendations for defining the respective indications for open surgical and interventional treatment were published for the second time under the name TASC II (Norgren et al 2007).

Interventional treatment is recommended for a constellation of findings of type A and surgical treatment for type D. Findings of types C and D can be treated by surgical or interventional means, depending on the patient's general health and the experience of the attending physicians.

Aortoiliac Occlusive Disease

Type A:
- Unilateral or bilateral stenoses of the common iliac artery
- Unilateral or bilateral short stenoses (< 3 cm) of the external iliac artery

Type B:
- Short stenoses (< 3 cm) of the infrarenal aorta
- Unilateral occlusion of one common iliac artery
- Isolated or multiple stenoses of one external iliac artery with a total length of 3 to 10 cm and not extending into the common femoral artery
- Unilateral occlusion of the external iliac artery not extending to the origin of the common femoral artery

Type C:
- Bilateral occlusion of the common iliac arteries
- Bilateral stenoses of the external iliac arteries with a total length of 3 to 10 cm and not extending to the origin of the common femoral artery
- Unilateral stenosis of the external iliac artery extending into the common femoral artery
- Unilateral occlusion of the external iliac artery with involvement of the origin of the internal iliac or common femoral arteries or both
- Severely calcified unilateral occlusion of the external iliac artery with or without involvement of the origins of the internal iliac or common femoral arteries

Type D:
- Infrarenal occlusion of the aorta
- Diffuse bilateral disease of the aorta and iliac arteries requiring treatment
- Diffuse multiple unilateral stenoses of the common iliac, external iliac, and common femoral arteries
- Unilateral occlusion of the common iliac and external iliac arteries
- Bilateral occlusion of both external iliac arteries
- Stenoses of the iliac arteries in patients with an aortic aneurysm requiring treatment but unsuitable for an endoprosthesis, or with other disorders requiring open surgery of the aorta or iliac arteries

Occlusive Disease of the Leg Arteries

Type A:
- Isolated stenosis < 10 cm long
- Isolated occlusion < 5 cm long

Type B:
- Multiple stenoses or occlusions, each < 5 cm long
- Isolated stenosis or occlusion < 15 cm long without involvement of the distal popliteal artery
- Isolated or multiple lesions in the absence of continuous arteries of the lower leg suitable as recipient vessels for a distal bypass
- Severely calcified occlusion < 5 cm long
- Isolated popliteal artery stenosis

Type C:
- Multiple stenoses or occlusions > 15 cm total length with or without severe calcification
- Recurrent stenosis or occlusion requiring treatment after two endovascular interventions

Type D:
- Chronic total occlusion of the common femoral artery or superficial femoral artery > 20 cm and involving the popliteal artery
- Chronic total occlusion of the popliteal artery and the proximal arteries of the lower leg (trifurcation)

However, Sixt et al (2008) demonstrated in a study published in 2008 that the TASC II recommendations are not necessarily to be interpreted as binding guidelines. In 375 patients with aortoiliac disorders, nearly identical results were achieved for the four TASC II classifications (primary patency rates after 1 year were 89, 86, 86, and 85%). The conclusions drawn by Conrad et al (2009) for the arteries of the leg were very similar. Assisted patency after 3 years was 94.3% for TASC II categories A and B, and 89.7% for categories C and D.

In everyday practice one should invariably consult one's surgeon when deciding whether to opt for surgical or interventional treatment. Regular consultations conducted candidly and without regard for personal ambition will quickly give each individual a realistic idea of the other specialist's skills. This in turn will help one to decide which treatment is indicated. Familiarity with the TASC II recommendations makes it easier to define reasonable limits of one's capabilities with respect to the surgeon and also with respect to patients' expectations.

It is wise to avoid the pitfall of viewing the surgeon as a rival. When in doubt self-restraint may be the best policy. It is a bitter setback when to fail after having argued in favor of treating a specific patient. The converse is true when one overcomes one's own hesitation and complies with a colleague's request that one treat a difficult case.

The literature documents the following trends over the last 10 to 15 years:

- Even in the arteries of the leg (especially in the thigh), endovascular procedures have become established as the treatment of choice.
- They are employed early and are often combined with endovascular interventions at other levels (pelvis and lower leg). This is presumably the reason for a decrease in the rate of amputation by 25 to 38% over 10 years (Egorova et al 2010, Goodney et al 2009).
- In the superficial femoral artery the primary patency rates are significantly worse than in the iliac arteries. However, good middle-term results have been achieved with second interventions.
- As expected, the results correlate with the TASC categories, although the differences are small (DeRubertis et al 2007).
- In contrast to the coronary arteries the processes that lead to recurrent stenosis in the arteries of the leg are not complete within 6 months (Shammas 2009). Optimal results require the following:
  - Excellent angiographic results of intervention with little dissection and residual stenosis
  - Protection of the arteries of the lower leg and reduction in the growth of smooth muscle cells by means of pharmacological intervention

Consultation with the Patient

It is a privilege to be able to conduct the consultation with the patient prior to obtaining informed consent. It is one of the most noble tasks the physician performs. Only this consultation can create the trust the patient needs to believe or even to know for certain that one can help, that one is the right physician to perform this intervention. For the physician as well it is of great importance to know that he has gained the patient's trust. This person believes in the chances of improvement and is not terrified of all the possible complications described in the patient handout.

Naturally the patient must be informed about possible risks, and patient handouts are clearly helpful in listing them comprehensively. Yet one shudders at the thought that patients should simply sign a form relinquishing all control to a physician they have never met. This reflects poorly on those physicians who never took the opportunity to place the long list of risks in perspective and to kindle their patient's trust in the far greater chance of improvement or healing.

> Whenever possible, one should not leave it to the family doctor, the attending physician on duty on the ward, or a younger colleague to discuss the procedure with the patient and obtain informed consent.
> Just do it yourself! One should speak so the patient will understand. And above all, one should listen and have the patient describe his or her complaints. One should ask questions in a way that leads the patient to those details that are of importance. In simple words one should describe what can presumably be done to address these complaints, and describe how it all works. If there is anything left to the patient handout let it be all the rare complications.

The patient is supposed to relinquish all control, and one will be doing something to the patient that he or she is unfamiliar with and barely understands. Therefore one must make a concerted effort to win the patient's trust. The patient must believe that what one will do will be helpful and necessary and that one can do it well. If this trust is gained, one will rarely find it necessary to prescribe preoperative sedatives.

Is it possible to imagine that any surgeon would fail to visit his or her patients on the afternoon or evening after their operation? The same applies to radiologists if they are to be perceived as responsible physicians. This is also the only way to establish a good working relationship with the ward. Nurses learn what specific aftercare radiological procedures require, how to recognize complications requiring treatment, and how to distinguish them from harmless findings. For example, a little blood seeping from the needle path into the bandage after closure of the artery with Angio-Seal (Kensey Nash, Exton, PA, USA) does not represent postprocedure bleeding.

Those radiologists who visit their patients after the procedure will experience some of life's most beautiful moments!

One other important thing develops from these interpersonal contacts: Coworkers and patients will experience one as a good physician in whom they can confide. Colleagues in one's own department and in the vascular surgery department are best able to evaluate how well one performs one's interventions. Others can only assess one's performance by how humanely one deals with patients (and coworkers) and by how one involves everybody at the workplace and on the ward with whom one shares the responsibility of caring for patients.

Everyone who shares with the responsibility for caring for one's patients should know that those patients are in good hands. They will pass this confidence on to patients in many ways. And in their anxiety and doubt, patients are thankful for every sign that shows them the right physician is treating them.

Preparing the Patient

A history is obtained and clinical findings documented before it is determined that intervention is indicated. Here it is especially important to identify high-risk patients. As a rule this will be done by another physician. One will see that patient on the day before the intervention, if not earlier, and have the patient describe his or her complaints and discuss with the patient which, if any, particular risks to be alert to.

To ensure the intervention proceeds smoothly it is important to verify at this stage that all necessary documentation is on hand or will be available the next day at the latest. At a minimum this includes the international normalized ratio (INR) value and serum creatinine level. However, it should also include findings and images of any previous angiographic examinations and interventions, computed tomographic (CT) and magnetic resonance imaging (MRI) studies, and ultrasonographic findings.

Coagulation

The INR value is routinely determined before every intervention. INR values of up to ~2.0 are usually regarded as harmless unless obesity or hypertension renders treatment of the access site more difficult. In patients who depend on INR values in the therapeutic range, oral anticoagulation must be gradually substituted by heparin prior to the intervention. During the procedure, all patients are regularly given unfractionated heparin.

Platelet Aggregation Inhibitors

At least 2 hours before the intervention each patient receives 100 mg of oral acetylsalicylic acid or 500 mg intravenously. Where a stent is implanted, the patient receives clopidogrel for 6 weeks. An initial saturation dose of 300 mg is administered on the first day and a daily dose of 75 mg thereafter. If placement of a stent is planned from the outset, then the saturation dose is administered on the day before the procedure.

Impaired Kidney Function

Serum creatinine is routinely determined before contrast administration. Note that a normal value does not exclude renal functional impairment. Serum creatinine increases over the normal value of 1 to 1.1 mg/dL only when the glomerular filtration rate (GFR) drops to 50%.

- With **slight renal insufficiency** (creatinine 1.0 to 1.5 mg/dL) have the patient drink a lot of fluids: 1 L before and after the intervention.
- With **moderate or severe renal insufficiency** (creatinine > 1.5 mg/dL), administer 0.9% saline solution 1 mL/kg body weight/h 12 hours before and 12 hours after the intervention.

In the presence of simultaneous heart failure, a 5% glucose solution is administered in place of the saline solution, and the infused fluid may be balanced against the volume of urine. Contrast should be used extremely sparingly and replaced with CO_2 wherever possible. Diuretic agents should be discontinued wherever possible.

> In patients with renal insufficiency do not administer contrast again for the next 2 days.

Diabetes

Diabetics receiving metformin must discontinue the medication on the day of treatment and not resume until 24 hours after contrast administration. With diabetics, one should carefully consider the possibility of renal insufficiency and should keep the contrast dose as low as possible.

Hyperthyroidism

Where there is the slightest suspicion of thyroid dysfunction, one should determine the thyroid-stimulating hormone (TSH) level to exclude latent hyperthyroidism. In cases of elevated TSH consultation with an endocrinologist is recommended.

Adverse Reaction to Contrast Agents

> **Important:** It is not the iodine but the organic carrier molecule that is responsible for adverse reactions that may occur. If a patient did not tolerate a certain contrast agent in a previous examination, then a different preparation must now be selected to minimize the risk of a second reaction.

Naturally, prophylactic administration of cortisone and antihistamines is indicated in any patient with a history of previous contrast intolerance. The patient is given 30 to 50 mg of oral prednisolone on the evening before and 2 hours before the procedure, and antihistamines shortly before the intervention: slow intravenous injection (sequentially, not mixed together) of one ampoule each of Fenistil (dimethindene maleate, H1 receptor blocker) (Novartis, East Hanover, NJ, USA) and Tagamet (cimetidine, H2 receptor blocker) (GlaxoSmithKline, Research Triangle Park, NC, USA).

In patients with a history of severe reaction to a contrast agent, one should consider whether it is possible to dispense with contrast agents entirely and use carbon dioxide instead.

On the Day of the Examination

When one receives the patient on the day of the examination one should briefly recapitulate the most important points of the previous day's discussion. As soon as the patient is on the examining table, one should check the peripheral pulses and examine the planned site of the approach in particular, using fluoroscopy with a metal object to determine the access site. Also a possible alternate site should be identified. Then venous access is established in the arm and local anesthesia is applied for the arterial access. It is generally sufficient to use 10 mL of a 1% local anesthetic.

Radiation Protection

In no other radiologic specialty are physicians and their assistants exposed to as much ionizing radiation as in interventional radiology. This makes information about how to minimize unnecessary exposure all the more important.

Make it a rule to work with pulsed fluoroscopy, using the lowest possible pulse frequency that provides sufficient image quality. It goes without saying that each use of fluoroscopy and every imaging series should be no longer than absolutely necessary. The influence of **collimation** is even more important. Failing to limit the fluoroscopic field to the smallest possible area can easily double the radiation dose for both patient and physician. This also decreases image quality significantly.

One must always remember this: Collimation is the most important factor in the following:

- Radiation protection
- Image quality

Most units are designed so that the X-ray tube is located beneath the patient and the image intensifier is above the patient. The exit dose on the patient (above) is only ~1% of the entrance surface dose (below). This means that the physician and assistants will be exposed to significantly more intense radiation in the lower half of their body than in the upper half unless steps are taken to block this scattered radiation. For this reason the examining table is equipped with lead curtains containing a thicker layer of lead than that in the protective apron worn on the body.

Upper body structures that require particular protection include the lenses of the eyes and the thyroid gland. Therefore one should never work without both lead-glass spectacles (which include side protection) and a thyroid shield. Alternatively or in addition, one may use a lead-glass shield suspended from the ceiling on a mobile mount and draped in a sterile fashion.

The examiner's hands are often very close to the fluoroscopic field. This makes narrow collimation particularly important. With a very small fluoroscopic field, one should switch off the automatic dose regulation with the lock-in function before collimating. The hand should not be placed in the path of the beam unless it is unavoidable. One should consider beforehand how to minimize radiation exposure in this situation. Finger exposure can be checked with a personal dosimeter worn regularly on a finger ring.

For most patients, especially older ones, the risk of radiation exposure involved in an intervention is a secondary consideration. Protection of the gonads is recommended in patients of reproductive age. When working in the vicinity of the gonads, the physician should carefully collimate the beam to keep the gonads out of the fluoroscopic field.

Erythema has occasionally been observed. However, this damage occurred only where the beam remained focused on a certain area for an extremely long time without changing direction. This is hardly ever the case in peripheral endovascular interventions.

References

Conrad MF, Kang J, Cambria RP, et al. Infrapopliteal balloon angioplasty for the treatment of chronic occlusive disease. J Vasc Surg 2009;50(4):799–805.e4

DeRubertis BG, Pierce M, Chaer RA, et al. Lesion severity and treatment complexity are associated with outcome after percutaneous infra-inguinal intervention. J Vasc Surg 2007;46(4):709–716

Egorova NN, Guillerme S, Gelijns A, et al. An analysis of the outcomes of a decade of experience with lower extremity revascularization including limb salvage, lengths of stay, and safety. J Vasc Surg 2010;51(4):878–885, 885.e1

Goodney PP, Beck AW, Nagle J, Welch HG, Zwolak RM. National trends in lower extremity bypass surgery, endovascular interventions, and major amputations. J Vasc Surg 2009;50(1):54–60

Momsen AH, Jensen MB, Norager CB, Madsen MR, Vestersgaard-Andersen T, Lindholt JS. Drug therapy for improving walking distance in intermittent claudication: a systematic review and meta-analysis of robust randomised controlled studies. Eur J Vasc Endovasc Surg 2009;38(4):463–474

Norgren L, Hiatt WR, Dormandy JA et al. Inter-Society Consensus for the Management of Peripheral Arterial Disease (TASC II). Eur J Vasc Endovasc Surg 2007;33 (Suppl 1):S1–S75

Shammas NW. Restenosis after lower extremity interventions: current status and future directions. J Endovasc Ther 2009; 16(Suppl 1):I170–I182

Sixt S, Alawied AK, Rastan A, et al. Acute and long-term outcome of endovascular therapy for aortoiliac occlusive lesions stratified according to the TASC classification: a single-center experience. J Endovasc Ther 2008;15(4):408–416

2 Material

Size Specifications for Cannulas, Guidewires, Catheters, and Sheaths

The unit "gauge" for cannulas (referring to the outer diameter) corresponds to the number of processing steps required to produce wire of the same diameter. Thus thick cannulas have low gauge numbers and thin cannulas high ones. The diameter of guidewires is specified in thousandths of an inch (1 in. = 2.54 cm). Sizes of catheters and sheaths are specified using the French scale (one French unit = 0.33 mm in diameter).

Note: The catheter size refers to the **outer diameter**, whereas the sheath size refers to the **inner diameter:** A 5 French catheter fits into a 5 French sheath, which in turn has an outer diameter of ~7 French, depending of course on the material. This occasionally causes some confusion, such as when the recommended material for an intervention includes a 6 French guiding sheath or, alternatively, an 8 French guiding catheter.

Cannulas

Vascular access to an artery or a deep vein is best established with a simple open 18 gauge cannula measuring 7 or 9 cm in length (**Fig. 2.1**). A 19 gauge, thin-walled cannula is sufficient for 0.035 in. wires. The cannula must be sharp; a blunt cannula compresses the vessel instead of passing through the proximal wall into the lumen.

For a long time three-piece **Seldinger cannulas** were used. A double mandrin sealed the lumen of the cannula during the puncture. Because no blood escaped, it was impossible to determine when the tip of the needle had entered the vascular lumen. Often the needle was advanced through the distal wall of the vessel as well. This was nearly unavoidable because the cannulas were almost invariably blunt; they were reused time and again and only occasionally resharpened. Finally the double mandrin was removed and the cannula withdrawn until blood flowed. The puncture of the distal wall that usually occurred was both unnecessary and harmful. Thankfully, this puncture technique has largely fallen from favor.

Some physicians use cannulas with plastic sheathing. This puncture technique is really only suitable for superficial vessels that can be punctured at a very acute angle.

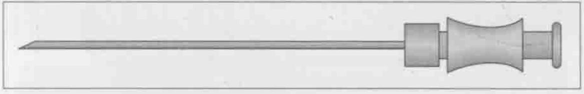

Fig. 2.1 Angiography cannula.

In deeper vessels it is often necessary to shift the cannula to a more acute angle once it enters the vascular lumen. This makes it easier to advance the guidewire into the vessel. Naturally this cannot be done with a plastic cannula.

In small superficial arteries (brachial and radial arteries), one may prefer not to use the comparatively large 18 or 19 gauge cannulas. Alternatively, one may make the puncture with a small cannula (21 gauge = 0.8 mm outer diameter, preferably only 4 cm long) and insert a 0.018 in. wire. The track is then expanded with the dilator of the appropriate sheath to permit insertion of catheters of 5, 6, or 7 French diameter depending on the sheath size (e.g., the Cook KCFN [Cook Medical, Bloomington, IN, USA], **Fig. 2.2**). The advantage of this technique is that it requires significantly less force to insert the cannula through the wall of the vessel. This means that the artery is less likely to slip away from the cannula, it will not collapse as easily before the cannula, and perforation of the distal wall may be more easily avoided.

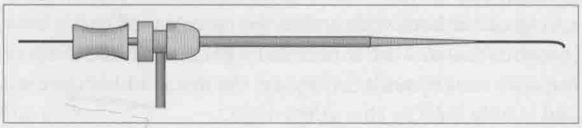

Fig. 2.2 Sheath of 5, 6, or 7 French diameter with a dilator for a 0.018 in. nitinol wire that fits a 21 gauge cannula (Cook Medical).

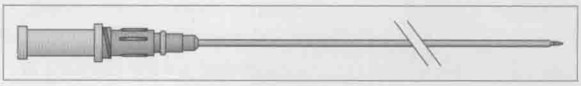

Fig. 2.3 Catheter cannula, 18 gauge, with a length of 18 cm (Cook Medical).

An 18 gauge catheter cannula 18 cm long (**Fig. 2.3**) can be very helpful in various situations: not the metal cannula but the plastic sheathing that has the same diameter as the customary puncture cannulas but is longer and more flexible. (A 4 French dilator may used in a similar manner. It is only slightly thicker, although less flexible.) Following are three examples:

- A **vessel wall is so hard** that it is impossible to introduce a sheath over the normal wire. This is almost always remedied with the aid of an Amplatz guidewire (Boston Scientific, Natick, MA, USA). Introduce the long plastic cannula over the normal wire and then insert the Amplatz guidewire through this cannula.
- In **antegrade catheterization** the wire comes to rest in the deep femoral artery. Before a larger hole is opened in the artery it should be determined whether the puncture has come too close to the deep femoral artery or has even punctured that artery. Switch to the long flexible plastic cannula. It is now possible to verify correct access far more reliably than with the rigid metal cannula.
- When a patient has **trophic changes** in one or both feet (stage IV occlusive disease according to Fontaine), it is important to determine whether stenoses or occlusions of the arteries of the leg are present and require treatment. When the inguinal pulses are strong and there is no other sign of iliac arterial stenosis, the examination can be limited to angiography of the lower legs using an antegrade approach in anticipation of possible intervention:
  - Perform the puncture with the normal steel cannula.
  - Then switch to the plastic cannula over a short wire.
  - Perform angiography.
  - Determine whether intervention is indicated.

Guidewires

The guidewire acts as the "rail" over which the catheter (according to Seldinger 1953) or sheath is introduced into the vessel (see Chapter 3). It allows curved and straight catheters to glide through vessels while preventing the catheter tip from injuring the vascular wall. Catheters or sheaths can be guided around curves and across bifurcations only with the aid of guidewires. They are the most important instrument in the interventional management of stenoses and occlusions.

Every guidewire is composed of a **metal core** that determines its stiffness and **flexible cladding**. This is because a bare steel wire 0.9 mm in diameter would be far too stiff for most functions. The 0.035 in. wire (see **Table 2.1** for units) is the most common wire thickness used in peripheral vessels today. Its core is a steel wire with a diameter between 0.35 and 0.44 mm (**Fig. 2.4**). It achieves its diameter of 0.9 mm because an outer wire 0.23 to 0.27 mm in diameter is wrapped around the core much like on the string of a guitar or piano. This type of wire is referred to as spring wire. Most wire designs have a fine straplike "safety wire" running longitudinally beneath the spring coil. This safety wire is fused to the spring coil at both ends and to the core as well at the back (proximal) end. This is necessary because the soft tip of the wire usually projects beyond the distal end of the core and is only held by this safety wire.

The surface of the steel wire is usually covered with a thin coating of Teflon. This coating doubles the lubricity of the wire when moistened (Schröder 1993c). In between these normal spring wires and the extremely stiff

Table 2.1 Comparison of the customary size specifications for cannulas, guidewires, and catheters

mm	Cannulas (gauge)	Guidewires (inches)	Catheters (French)
0.3		0.012	
0.36		0.014	
0.46		0.018	
0.5	25		
0.8	21		
0.9	20	0.035	
1.0		0.038	3
1.1	19		
1.2	18		3.6
1.33			4
1.67			5
2.0			6
2.33			7
2.67			8
3.0			9