

152256

Vascular Diagnosis with Ultrasound

Clinical Reference with Case Studies

Volume 1: Cerebral and Peripheral Vessels

Michael G. Hennerici

Doris Neuerburg-Heusler

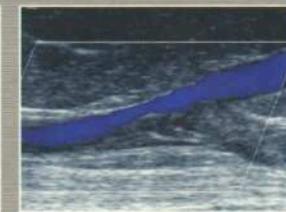
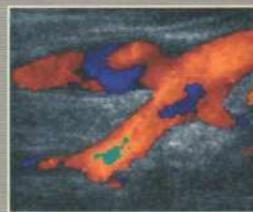
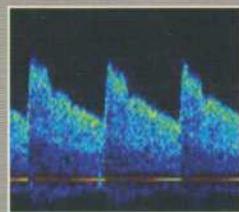
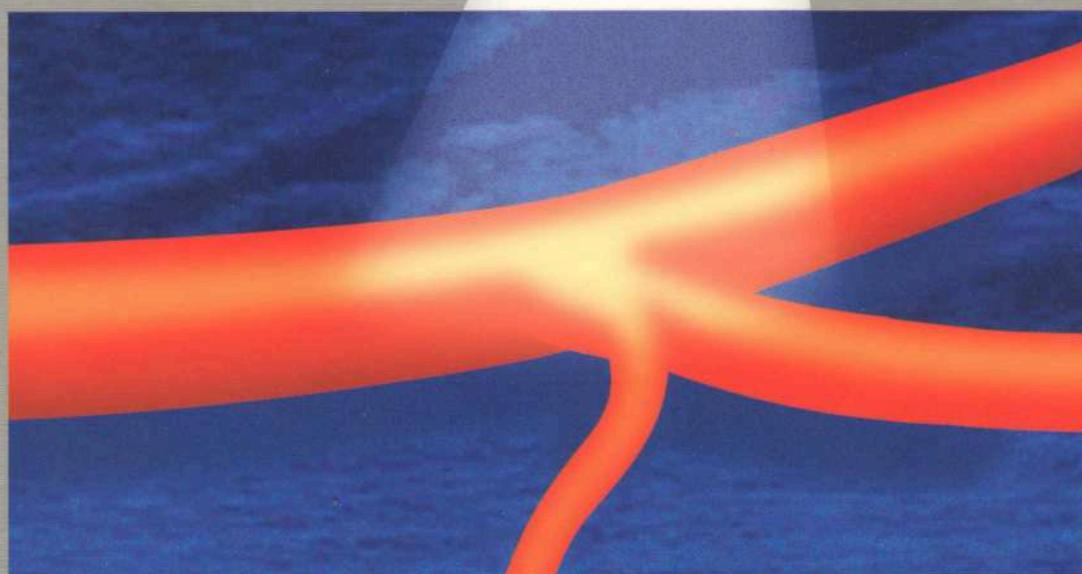
and

Michael Daffertshofer

Thomas Karasch

Stephen Meairs

2nd revised edition



Thieme

Table of Contents

1 Physics and Technology of Ultrasound 1

Basic Ultrasound Physics	1
Properties of Waves	1
Reflection	1
Refraction	2
Scattering and Diffraction	2
Attenuation	2
Intensity and Power	2
The Doppler Effect	2
Ultrasound Technology	3
Doppler Systems	3
Continuous-Wave Doppler Sonography	3
Pulsed-Wave Doppler Sonography	3
B-Mode Imaging	6
Color Doppler Flow Imaging	7
Power Doppler Imaging	9
Duplex Systems	9
Compound Imaging	10
B-Flow Imaging	10
Transducers	11
Signal Analysis	12
Audio Signal Analysis	12
Zero-Crossing Counter	12
Time-Interval Histograms	13
Spectral Analysis	13
Three-Dimensional Ultrasound	14
Image Acquisition	15
Monitoring Spatial Position	15
Computerized Motor-Driven Systems	15
Semiregistration Techniques	15
POM Scanhead Tracking	16
Reconstruction Techniques	16
Visualization Techniques	16
Four-Dimensional Applications	17
Contrast Imaging	18
Nonlinear Characteristics of Microbubbles	18
Microbubble Destruction	18
Low Mechanical Index Imaging	19
Stimulated Acoustic Emission	19
Harmonic Imaging	19
Pulse Inversion Harmonic Imaging	20
Power Pulse Inversion Imaging	20
Microvascular Imaging	20
Microbubble Refill Kinetics	21
References	22

2 Extracranial Cerebral Arteries 27

Examination	27
Special Equipment and Documentation	27
Examination Conditions	27
Patient and Examiner	27
Conducting the Examination	27
Examination Sequence	29
Orbital Arteries	29
Neck Arteries	29
Common Carotid Artery	29
Internal and External Carotid Arteries	31
Vertebral–Subclavian System	33
Vertebral Artery	33
Subclavian Artery	36
Innominate Artery (Brachiocephalic Trunk)	36
Thoracic Aorta	36
Anatomy and Findings	36
Anatomy	36
Findings	37
Evaluation	37
Sources of Error	37
Neck Arteries	38
Principle	38
Anatomy and Findings	39
Carotid System	39
Anatomy	39
Common Carotid Artery	39
Internal Carotid Artery	41
External Carotid Artery	43
Vertebral–Subclavian System	44
Anatomy	44
Vertebral Artery	44
Subclavian Artery	45
Innominate Artery–Aortic Arch	46
Evaluation	46

Sources of Error	47
Ultrasound Incident Angle	47
Cardiac Arrhythmia	47
Vascular Width	47
Anomalies in the Vascular Course	47
Venous Superimposition	47
Echogenicity	48
Postintervention	48
Diagnostic Effectiveness	50
Pathological Findings	52
Orbital Arteries	52
Principle	52
Findings	52
Evaluation	53
Sources of Error	53
Diagnostic Effectiveness	54
Carotid System	55
Principle	55
Findings	62
Common Carotid Artery	62
Internal Carotid Artery	65
External Carotid Artery	69
Evaluation	71
Vascular Degeneration and Atherosclerosis	71
Internal Carotid Artery Stenosis	71
Internal Carotid Artery Occlusion	71
Carotid Bifurcation Stenosis	72
Internal Carotid Artery Occlusion and Ipsilateral External Carotid Artery Stenosis	72
External Carotid Artery Occlusion and Internal Carotid Artery Stenosis	72
Supra-Aortic System	80
Principle	80
Findings	80
Subclavian Artery	80
Obstruction Proximal to the Origin of the Vertebral Artery	81
Obstruction Distal to the Origin of the Vertebral Artery	81
Innominate Artery	81
Aortic Arch	81
Evaluation	82
Sources of Error	82
Diagnostic Effectiveness	82
References	82
Sequential Ipsilateral Stenoses in the Carotid System	72
Multivessel Disease	73
Carotid Artery Dissection	73
Postoperative Findings	73
Postinterventional Findings (Stenting)	73
Sources of Error	73
Diagnostic Effectiveness	74
Vertebral Artery System	75
Principle	75
Findings	75
Increased Flow Velocities	76
Decreased Flow Velocities	76
Slosh Phenomenon	77
Intermediate Blood Flow	77
Absent Signal	77
Retrograde Blood Flow	78
Evaluation	78
Sources of Error	78
Diagnostic Effectiveness	79

3 Intracranial Cerebral Arteries

89

Examination	89
Special Equipment and Documentation	89
Examination Conditions	90
Patient and Examiner	90
Conducting the Examination	91
Ultrasound Application and Probe Position	91
Transtemporal Ultrasound	91
Transorbital Ultrasound	91
Transnuchal Ultrasound	92
Ophthalmic Artery and Internal Carotid Artery (Siphon)	92
Middle Cerebral Artery (MCA)	92
Anterior Cerebral Artery (ACA)	94
Intracranial Internal Carotid Artery and T-Junction	94
Posterior Cerebral Artery (PCA)	94
Vertebral Artery (VA)	94
Basilar Artery (BA)	95
Functional Tests	96
Compression Tests	96
Vasomotor Reactivity Tests	97
CO ₂ Reactivity Test	97
Autoregulation Tests	98
Vasoneural Coupling	101
Posterior Cerebral Artery Stimulation	101
Middle Cerebral Artery Stimulation	102
Techniques	103
Transcranial Monitoring (TCM)	103
Ultrasound Contrast Administration	104
Normal Findings	105
Principle	105
Anatomy and Findings	106
Carotid Siphon—Ophthalmic Artery	106
Anatomy	106
Findings	106
Middle Cerebral Artery	107
Anatomy	107
Findings	107
Anterior Cerebral Artery and Anterior Communicating Artery	108
Anatomy	108

Findings	108
Normal Values	109
Posterior Cerebral Artery and Posterior Communicating Artery	109
Anatomy	109
Findings	109
Vertebral Artery and Basilar Artery	109
Anatomy	109
Findings	109
Functional Tests	110
Compression Tests	110
Vasomotor Reactivity Test	110
CO ₂ Reactivity Tests	111
Autoregulation Tests	112
Vasoneural Coupling	112
Monitoring	113
Evaluation	113
Sources of Error	114
Weak or Absent Signals	114
Anatomical Reasons for Error	114
Technical Artifacts	114
Hemodynamic Causes	114
Pathophysiological Causes	114
Identification Problems	115
Diagnostic Effectiveness	115
Pathological Findings	115
Principle	115
Findings	117
Stenoses	117
Occlusions	118
Collateralization of Extracranial Carotid Artery Obstructions	120
Evaluation	121
Dilative Arteriopathy	121
Carotid Cavernous Fistula	121
Arteriovenous Malformation	121
Spasms and Aneurysms	122
Extracranial-Intracranial Bypass	123
Increased Intracranial Pressure and Cerebral Circulatory Arrest	124
Intracranial Findings in Steal Phenomena	125
Functional Disturbances	125
Monitoring	126
Acute Stroke	126
Spontaneous Microemboli (MES) and High-Intensity Signals (HITS)	128
Monitoring During Interventional Procedures	128
Right-to-Left Shunt Detection	128
TCD and Migraine	129
TCD and Epilepsy	129
Sources of Error	129
Incorrect Anatomic Identification of Flow Accelerations	129
Absent Signal	129
Inadequate Control	129
Normal Variants	129
Special Applications	129
Brain Structure Imaging	129
Hemorrhage, Midline Shift	130
Tissue Perfusion	130
Diagnostic Effectiveness	131
References	132

4 Cerebral Veins

139

Examination	139
Special Equipment and Documentation	139
Examination Conditions	139
Patient and Examiner	139
Conducting the Examination	139
Functional Tests (Provoked Flow Signals)	139
Normal Findings	139
Anatomy and Findings	139
Extracranial Veins—Internal Jugular Vein ..	141
Intracranial Veins	142
Evaluation	143
Pathological Findings	143
Principle	143
Findings	143
Extracranial Veins	143
Jugular Vein Thrombosis	143
Ectasias and Aneurysms	143
Venous Congestion	143
Arteriovenous Fistulas	143
Intracranial Veins	143
Sinus Thrombosis	143
Cavernous Sinus Fistula	145
Arteriovenous Malformations	145
Venous Malformations	146
Evaluation	146
Sources of Error	146
Diagnostic Effectiveness	146
References	147

5 Peripheral Arteries

149

Systolic Blood-Pressure Measurement	149
Examination	149
Special Equipment and Documentation	149
Examination Conditions	149
Patient and Examiner	149
Conducting the Examination	149
Examination Sequence	150
Pelvic and Leg Arteries	150
Measurement of Pressure at Rest	150
Measurement of Pressure Post	
Exercise	150
Measurement of Segmental Pressure	151
Measurement of Toe Pressure	151
Upper Extremity Arteries	151
Measurement of Digit Pressure	151
Normal Findings	151
Principle	151
Findings	153
Pelvic and Leg Arteries	153
Measurement of Pressure at Rest	153
Measurement of Pressure Post	
Exercise	153
Measurement of Segmental Pressure	153
Upper Extremity Arteries	153
Evaluation	154
Measurement of Ankle Pressure	154
Measurement of Toe Pressure	155
Measurement of Digit Pressure	155
Pathological Findings	155
Principle	155
Findings	156
Pelvic and Leg Arteries	156
Measurement of Pressure at Rest	156
Measurement of Pressure Post	
Exercise	157
Measurement of Segmental Pressure	157
Measurement of Toe Pressure	158
Upper Extremity Arteries	158
Measurement of Pressure at Rest	158
Measurement of Pressure Post	
Exercise	158
Measurement of Digit Pressure	158
Evaluation	158
Sources of Error	159
Diagnostic Effectiveness	159
Color Flow Duplex Sonography and Continuous-Wave Doppler Sonography	161
Examination	161
Special Equipment and Documentation	161
Examination Conditions	161
Patient and Examiner	161
Conducting the Examination	163
Examination Sequence	163
Pelvic and Leg Arteries	163
Upper Extremity Arteries	165
Normal Findings	166
Principle	166
Findings and Anatomy	167
Pelvic Level	167
Thigh Level	168
Calf and Foot Arteries	170
Upper Extremity Arteries	170
Evaluation	171
Pathological Findings	173
Grading of Stenoses	174
Principle	174
Principle of the Continuity Equation	174
Principle of the Bernoulli Equation	176
Findings	176
Pelvic Level	176
Thigh Level	178
Calf and Foot Arteries	180
Upper Extremity Arteries	181
Subclavian Artery and Arm Arteries	181
Arteries of the Hand and Fingers	182
Special Sets of Findings	182
Neurovascular Compression Syndrome of the Shoulder Girdle	182
Examination and Findings	182
Hypothenar Hammer Syndrome	183
Endothelial Dysfunction	183
Inflammatory Vascular Diseases	183
Thromboangiitis Obliterans (Winiwarter-Buerger Disease)	183
Takayasu Arteritis	184
Entrapment Syndrome	184
Cause	184
Classification	185
Findings	185
Effects of Compression	185
Provocation Maneuvers	185
Cystic Adventitial Degeneration	185
Findings	185
Aneurysms	185
True Aneurysm	186
Findings	186
False Aneurysm	187
Findings	188
Compression Therapy	188
Arteriovenous Fistulas	190
Principle and Etiology	191
Findings	191
Hemodialysis Shunt	191
Temporary Shunts	191
Monitoring Lumen Recanalization Techniques	192
Angioplasty and Stenting	192
Vascular Prostheses and Bypasses	193

Iatrogenic Arterial Dissection	194
Arterial Locks	194
Evaluation	195
Sources of Error	196
Diagnostic Effectiveness	198
References	203

6 Peripheral Veins

211

Examination	211
Special Equipment and Documentation	211
Examination Conditions	211
Patient and Examiner	211
Deep Pelvic and Leg Veins	212
Superficial Leg Veins	212
Upper Extremity Veins	212
Conducting the Examination	212
Pelvic and Leg Veins	212
Spontaneous Respiration (S-sounds) ...	213
Augmented Sounds (A-sounds)	213
Testing for Insufficiency of Perforating Veins	215
Upper Extremity Veins	215
Spontaneous Respiration (S-sounds) ...	216
Augmented Sounds (A-sounds)	216
Examination Sequence	216
Pelvic and Leg Veins	216
Upper Extremity Veins	217
Normal Findings	218
Principle	218
Anatomy and Findings	220
Pelvic and Leg Veins	220
Deep Venous System	220
Superficial Venous System	223
Perforating Veins	224
Upper Extremity Veins	225
Deep Venous System	225
Superficial Venous System	226
Perforating Veins	226
Evaluation	227
Patency Examination	227
Valvular Function	228
Pathological Findings	228
Principle	228
Findings	230
Pelvic and Leg Veins	230
Deep Venous System	230
Thrombotic Processes	231
Muscle Vein Thromboses	232
Valvular Insufficiency	233
Superficial Venous System	234
Collateral Veins	235
Thrombophlebitis	235
Perforating Veins	236
Upper Extremity Veins	236
Deep Venous System	236
Thrombotic Processes	236
Superficial Venous System	237
Special Sets of Findings	238
Congenital Venous Dysplasias	238
Klippel–Trénaunay Syndrome	238
F.P. Weber Syndrome	238
Servelle–Martorell Syndrome	238
Atypical Varicosis	238
Pelvic Venous Syndrome	238
Hemangiomas	238
Arteriovenous Fistulas	238
Venous Hypoplasia and Aplasia	239
Venous Valve Agenesis and Hypoplasia ...	239
Venous Aneurysms	239
Secondary Arteriovenous Fistulas	239
Acquired Venous Aneurysms	240
Evaluation	240
Thrombotic Processes	240
Valvular Insufficiency	241
Sources of Error	241
Diagnostic Effectiveness	243
Thrombotic Processes	243
Thrombosis of the Shoulder and Arm Veins	247
Post-Thrombotic Venous System	247
Age of Venous Thrombosis	248
Valvular Insufficiency	249
Insufficient Perforating Veins	249
Thrombophlebitis	250
Special Sets of Findings	250
References	250

7 Case Histories

257

Anatomical Overview	257
Documentation of Examination Report	261
Extracranial Arteries	263
1 Plaques (Right) and Mild Degree of Stenosis (Left) in the Internal Carotid Artery	263
2 Moderate Degree of Stenosis of the Right Internal Carotid Artery	264
3 Dissection of the Left Internal Carotid Artery	265

XII Table of Contents

4 Findings after Stent Placement	266
5 Multivessel Disease	268
6 Severe Stenosis of the Innominate Artery	271
7 Ipsilateral Multilevel Carotid Disease: Stenosis at the Siphon and the Bifurcation of the Left Internal Carotid Artery in the Neck ..	272
8 Permanent Subclavian Steal Phenomenon on the Left	274
9 Takayasu's Aortic Arch Arteries	276
10 Dissection of Both Vertebral Arteries	278
11 Stenosis of the Vertebrobasilar Arteries	280
 Intracranial Arteries	281
12 Stenosis of the Middle Cerebral Artery (Right M ₁ Segment)	281
13 MCA Occlusion due to Carotid Stenosis	282
14 Basilar Aneurysm due to Dolichoectasia	284
15 Transient Internal Carotid Artery Fistula on the Left	286
16 Acute Stroke Due to Middle Cerebral Artery Occlusion, with Spontaneous Recanalization	289
 Peripheral Arteries	292
Pelvic Level	292
17 Stenosis of the Iliac Artery \leq 50%	292
18 Stenosis of the Iliac Artery > 50%	294
19 Occlusion of the Iliac Artery	296
 Thigh Level	298
20 Stenosis of the Femoral Artery	298
21 Occlusion of the Femoral Artery (Short)	301
22 Occlusion of the Femoral Artery (Longer)	302
23 Occlusion of the Popliteal Artery	304
24 Aneurysm of the Femoral Artery	305
25 Aneurysm of the Popliteal Artery	308
26 False Aneurysm of the Common Femoral Artery (Spontaneous Course)	310
27 False Aneurysm (Compression Therapy)	312
28 Stenosis at a Bypass Insertion Point	314
29 Stent Stenosis in the Superficial Femoral Artery (Percutaneous Transluminal Angioplasty)	316
30 Bypass Rupture	318
31 Dissection of the Common Femoral Artery ...	320
 Arteries of the Lower Leg and Foot	322
32 Stenosis of the Tibiofibular Trunk (Percutaneous Transluminal Angioplasty)....	322
33 Occlusions of the Lower Leg Arteries	324
 Shoulder and Arm Arteries	325
34 Stenosis of the Brachial Artery	325
35 Occlusions of the Brachial Artery and Arteries of the Lower Arm (Neurovascular Compression Syndrome).....	327
36 Occlusions of the Digital Arteries	330
 Peripheral Veins	332
Thrombotic Processes	332
37 Iliac Vein Thrombosis	332
38 Thrombosis of the Femoral Vein	334
39 Partially Occluded Thrombosis of the Popliteal Vein	336
40 Thrombosis of the Iliac and Leg Veins (Spontaneous Palma-like Shunt)	338
 Aneurysm	339
41 Aneurysm of a Great Saphenous Vein Bypass	339
 Valvular Insufficiency	340
42 Varicosis of the Great Saphenous Vein	340
43 Insufficient Perforating Veins	342
 Upper Extremities	344
44 Subclavian Vein Thrombosis	344

8 Glossary

346

Index

356