

## Table of Contents

### 1 Physics and Technology of Ultrasound

1

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

### 2 Extracranial Cerebral Arteries

27

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

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

### 3 Intracranial Cerebral Arteries

89

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

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

**4 Cerebral Veins****139**

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

<b>5 Peripheral Arteries</b>	<b>149</b>
<b>Systolic Blood-Pressure Measurement</b> .....	149
<b>Examination</b> .....	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
<b>Normal Findings</b> .....	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
<b>Pathological Findings</b> .....	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
<b>Color Flow Duplex Sonography and Continuous-Wave Doppler Sonography</b> .....	161
<b>Examination</b> .....	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
<b>Normal Findings</b> .....	166
Principle .....	166
Findings and Anatomy .....	167
Pelvic Level .....	167
Thigh Level .....	168
Calf and Foot Arteries .....	170
Upper Extremity Arteries .....	170
Evaluation .....	171
<b>Pathological Findings</b> .....	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	Sources of Error .....	196
Arterial Locks .....	194	Diagnostic Effectiveness .....	198
Evaluation .....	195	References .....	203

**6 Peripheral Veins****211**

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

**7 Case Histories****257**

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

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
 <b>Intracranial Arteries</b> .....	281
12 Stenosis of the Middle Cerebral Artery (Right M <sub>1</sub> 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
 <b>Peripheral Arteries</b> .....	292
<b>Pelvic Level</b> .....	292
17 Stenosis of the Iliac Artery ≤ 50% .....	292
18 Stenosis of the Iliac Artery >50% .....	294
19 Occlusion of the Iliac Artery .....	296
 <b>Thigh Level</b> .....	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
 <b>Arteries of the Lower Leg and Foot</b> .....	322
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
 <b>Shoulder and Arm Arteries</b> .....	325
32 Stenosis of the Tibiofibular Trunk (Percutaneous Transluminal Angioplasty) ....	322
33 Occlusions of the Lower Leg Arteries .....	324
 <b>Peripheral Veins</b> .....	332
<b>Thrombotic Processes</b> .....	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
 <b>Aneurysm</b> .....	339
41 Aneurysm of a Great Saphenous Vein Bypass .....	339
 <b>Valvular Insufficiency</b> .....	340
42 Varicosis of the Great Saphenous Vein .....	340
43 Insufficient Perforating Veins .....	342
 <b>Upper Extremities</b> .....	344
44 Subclavian Vein Thrombosis .....	344

**8 Glossary**

**346**

**Index**

**356**