

Contents

1 Fundamental Principles.....	1
1.1 Technical Principles of Diagnostic Ultrasound	1
1.1.1 Gray-Scale Ultrasonography (B-Mode)	1
1.1.1.1 Historical Milestones	1
1.1.1.2 Sound Waves	1
1.1.1.3 Generating Ultrasound Waves.....	2
1.1.1.4 Physical Factors Affecting the Ultrasound Scan.....	2
1.1.1.4.1 Reflection and Refraction.....	3
1.1.1.4.2 Scattering.....	3
1.1.1.4.3 Interference.....	4
1.1.1.4.4 Diffraction	4
1.1.1.4.5 Attenuation and Absorption	4
1.1.1.5 Generating an Ultrasound Image	4
1.1.1.5.1 Pulse-Echo Technique	4
1.1.1.5.2 Time-Gain Compensation	4
1.1.1.5.3 A-Mode	5
1.1.1.5.4 B-Mode.....	5
1.1.1.5.5 M-Mode.....	5
1.1.1.6 Resolution	6
1.1.1.7 Beam Focusing.....	6
1.1.1.8 Types of Transducers.....	7
1.1.1.8.1 Principle of Operation	7
1.1.1.8.2 Linear Arrays.....	7
1.1.1.8.3 Curved or Convex Arrays.....	8
1.1.1.8.4 Sector Scanners	8
1.1.1.8.5 Phased Arrays.....	8
1.1.1.8.6 Mechanical Sector Scanners.....	8
1.1.1.8.7 Annular Phased Arrays.....	9
1.1.1.8.8 Disadvantages of Mechanical Transducers	9
1.1.1.9 Ultrasound Artifacts	9
1.1.1.9.1 Posterior Shadowing.....	9
1.1.1.9.2 Acoustic Enhancement.....	9
1.1.1.9.3 Edge Effect.....	9
1.1.1.9.4 Side Lobes.....	10
1.1.1.9.5 Reverberation Artifact.....	10
1.1.1.9.6 Geometric Distortion.....	11
1.1.2 Basic Physics of Doppler Ultrasound.....	11
1.1.2.1 Continuous Wave Doppler Ultrasound.....	12
1.1.2.2 Pulsed Wave Doppler Ultrasound/Duplex Ultrasound.....	13
1.1.2.3 Frequency Processing.....	13
1.1.2.4 Blood Flow Measurement.....	14

1.1.3	Physical Principles of Color-Coded Duplex Ultrasound.....	18
1.1.3.1	Velocity Mode.....	18
1.1.3.2	Power (Angio) Mode.....	20
1.1.3.3	B-Flow Mode (Brightness Flow).....	21
1.1.3.4	Intravascular Ultrasound.....	22
1.1.3.5	Three-Dimensional/Four-Dimensional Ultrasound.....	23
1.1.4	Factors Affecting (Color) Duplex Imaging – Pitfalls.....	23
1.1.4.1	Scattering, Acoustic Shadowing.....	23
1.1.4.2	Mirror Artifact.....	24
1.1.4.3	Maximum Flow Velocity Detectable – Pulse Repetition Frequency ...	24
1.1.4.4	Minimum Flow Velocity Detectable – Wall Filter, Frame Rate.....	27
1.1.4.5	Transmit and Receive Gain.....	28
1.1.4.6	Doppler Angle.....	28
1.1.4.7	Physical Limitations of Color Duplex Ultrasound.....	28
1.1.5	Ultrasound Contrast Agents.....	30
1.1.6	Safety of Diagnostic Ultrasound.....	32
1.1.6.1	Thermal Effects.....	32
1.1.6.2	Mechanical Effects.....	33
1.1.6.3	Specific Risks of Individual Ultrasound Techniques.....	33
1.2	Hemodynamic Principles.....	34
1.2.1	Laminar Flow.....	34
1.2.2	Flow Profiles and Perfusion Regulation.....	36
1.2.2.1	Low-Resistance Flow.....	36
1.2.2.2	High-Resistance Flow.....	36
1.2.2.3	Blood Flow Regulation.....	37
1.2.3	Determining the Degree of Stenosis.....	38
1.3	Machine Settings.....	42
2	Peripheral Arteries.....	45
2.1	Pelvic and Leg Arteries.....	45
2.1.1	Vascular Anatomy.....	45
2.1.1.1	Pelvic Arteries.....	45
2.1.1.2	Leg Arteries.....	45
2.1.2	Examination Protocol and Technique.....	47
2.1.2.1	Pelvic Arteries.....	47
2.1.2.2	Leg Arteries.....	48
2.1.3	Specific Aspects of the Examination from the Perspective of the Angiographer and Vascular Surgeon.....	49
2.1.4	Interpretation and Documentation.....	55
2.1.5	Normal Duplex Ultrasound of Pelvic and Leg Arteries.....	55
2.1.6	Abnormal Findings: Clinically Oriented Ultrasound Examination, Ultrasound Findings and Measurement Parameters, Diagnostic Role.....	56
2.1.6.1	Atherosclerotic Occlusive Disease.....	56
2.1.6.1.1	Pelvic Arteries.....	57
2.1.6.1.2	Leg Arteries.....	60
2.1.6.2	Arterial Embolism.....	71
2.1.6.3	Aneurysm.....	72
2.1.6.4	Rare Stenosing Arterial Diseases of Nonatherosclerotic Origin....	73
2.1.6.4.1	Adventitial Cystic Disease.....	75
2.1.6.4.2	Popliteal Entrapment Syndrome.....	76
2.1.6.4.3	Raynaud’s Disease.....	77
2.1.6.4.4	Paraneoplastic Disturbance of Acral Perfusion.....	79
2.1.6.4.5	Buerger’s Disease.....	79

2.1.6.4.6 Inflammatory Conditions.....	80
2.1.6.4.7 Chronic Recurrent Compartment Syndrome of the Calf.....	81
2.1.7 Follow-up After Surgical and Interventional Treatment	81
2.1.7.1 Thromboendarterectomy	81
2.1.7.2 Percutaneous Transluminal Angioplasty and Stenting.....	81
2.1.7.3 Bypass Graft Surveillance.....	83
2.1.7.3.1 Methodological Considerations and Stenosis Criteria	83
2.1.7.3.2 Controversy About the Benefit of Duplex Bypass Graft Surveillance Programs	86
2.1.7.4 Ultrasound Vein Mapping Prior to Peripheral Bypass Surgery	88
2.1.8 Role of (Color) Duplex Ultrasound Compared with Other Modalities: Problems and Pitfalls.....	89
2.2 Arm Arteries	92
2.2.1 Vascular Anatomy	92
2.2.2 Examination Protocol and Technique.....	93
2.2.3 Clinical Role of Duplex Ultrasound.....	94
2.2.3.1 Atherosclerosis.....	94
2.2.3.2 Compression Syndromes.....	94
2.2.4 Documentation	95
2.2.5 Normal Findings.....	95
2.2.6 Abnormal Findings, Duplex Ultrasound Measurements, and Clinical Role	95
2.2.6.1 Atherosclerosis.....	95
2.2.6.2 Compression Syndromes.....	95
2.3 Atlas: Peripheral Arteries	97
3 Peripheral Veins	165
3.1 Pelvic and Leg Veins.....	165
3.1.1 Vascular Anatomy	165
3.1.2 Examination Protocol.....	167
3.1.2.1 Thrombosis.....	167
3.1.2.2 Chronic Venous Insufficiency and Varicosis.....	170
3.1.3 Normal Findings.....	173
3.1.4 Documentation	174
3.1.4.1 Deep Vein Thrombosis of the Leg	174
3.1.4.2 Chronic Venous Insufficiency and Varicosis.....	174
3.1.5 Clinical Role of Duplex Ultrasound.....	174
3.1.5.1 Thrombosis and Postthrombotic Syndrome	174
3.1.5.2 Varicosis	178
3.1.6 Duplex Ultrasound – Diagnostic Criteria, Indications, and Role.....	181
3.1.6.1 Thrombosis.....	181
3.1.6.2 Chronic Venous Insufficiency	192
3.1.6.3 Varicosis	195
3.1.6.4 Varicophlebitis.....	198
3.1.7 Rare Venous Abnormalities.....	199
3.1.7.1 Venous Aneurysm	199
3.1.7.2 Tumors of the Venous Wall	201
3.1.7.3 Venous Compression.....	201
3.1.7.4 Adventitial Cystic Disease of Veins	201
3.1.7.5 Differential Diagnosis: Lymphedema, Lipedema	201
3.1.8 Vein Mapping	202
3.1.9 Diagnostic Role of Ultrasound.....	202
3.1.9.1 Thrombosis.....	202

3.1.9.2	Chronic Venous Insufficiency	206
3.1.9.3	Varicosis	208
3.2	Arm Veins and Jugular Vein	209
3.2.1	Vascular Anatomy	209
3.2.2	Examination Protocol and Technique.....	209
3.2.3	Normal Findings.....	209
3.2.4	Documentation	209
3.2.5	Clinical Role.....	210
3.2.6	Duplex Ultrasound Findings and Their Diagnostic Significance.....	210
3.2.7	Diagnostic Role of Duplex Ultrasound Compared with Other Modalities ..	211
3.3	Atlas: Peripheral Veins	213
4	Shunts.....	267
4.1	Clinical Role of Shunt Diagnosis	267
4.1.1	Background	267
4.1.2	Diagnostic Tasks in Patients with Spontaneous and Therapeutic Shunts.....	267
4.2	Examination Protocol, Technique, and Diagnostic Role	269
4.2.1	Congenital and Acquired Fistulae	269
4.2.2	Dialysis Access.....	269
4.3	Typical Shunt-Related Changes in the Doppler Waveform	271
4.4	Shunt Maturation and Flow Volume Measurement	271
4.5	Documentation.....	272
4.6	Vascular Mapping Prior to AV Fistula Creation	272
4.7	Abnormal Findings (Inadequate Dialysis).....	273
4.7.1	Shunt Stenosis	273
4.7.2	Peripheral Ischemia	275
4.7.3	Shunt Aneurysm.....	275
4.7.4	Abnormal Shunt Flow	276
4.8	Diagnostic Role of Duplex Ultrasound Compared with Other Modalities.....	276
4.9	Atlas: Shunts	278
5	Extracranial Cerebral Arteries.....	291
5.1	Normal Vascular Anatomy and Important Variants.....	291
5.2	Examination Technique and Protocol	294
5.2.1	Carotid Arteries	294
5.2.2	Vertebral Arteries	297
5.3	Documentation.....	299
5.4	Normal Findings	299
5.4.1	Carotid Arteries	299
5.4.2	Vertebral Arteries	299
5.5	Clinical Role of Duplex Ultrasound	299
5.5.1	Carotid Arteries	299
5.5.1.1	Defining the Degree of Stenosis.....	301
5.5.1.2	Plaque Morphology	305
5.5.2	Vertebral Arteries	306
5.6	Ultrasound Criteria, Measurement Parameters, and Diagnostic Role	306
5.6.1	Carotid Arteries	306
5.6.1.1	Plaque Evaluation and Morphology.....	306
5.6.1.2	Stenosis Quantification/Stenosis Grading	314
5.6.1.3	Occlusion.....	324
5.6.1.4	Postoperative Follow-Up.....	326
5.6.2	Vertebral Arteries	330
5.6.2.1	Stenosis	330
5.6.2.2	Occlusion.....	330

5.6.2.3	Dissection.....	330
5.6.2.4	Subclavian Steal Syndrome.....	331
5.7	Diagnosis of Brain Death.....	332
5.8	Rare (Nonatherosclerotic) Vascular Diseases of the Carotid Territory.....	332
5.8.1	Dissection	332
5.8.2	Inflammatory Vascular Diseases (Takayasu's Arteritis).....	334
5.8.3	Fibromuscular Dysplasia.....	335
5.8.4	Aneurysm	335
5.8.5	Arteriovenous Fistula	336
5.8.6	Idiopathic Carotidynia.....	336
5.8.7	Vasospasm	336
5.8.8	Compression by Tumor, Carotid Body Tumor.....	337
5.9	Diagnostic Role of Duplex Ultrasound in Evaluating the Extracranial Cerebral Arteries.....	337
5.10	Atlas: Extracranial Cerebral Arteries.....	341
6	Visceral and Retroperitoneal Vessels	377
6.1	Abdominal Aorta, Visceral and Renal Arteries	377
6.1.1	Vascular Anatomy	377
6.1.1.1	Aorta.....	377
6.1.1.2	Visceral Arteries.....	377
6.1.1.3	Renal Arteries.....	378
6.1.2	Examination Protocol and Technique.....	378
6.1.2.1	Aorta.....	378
6.1.2.2	Visceral Arteries.....	378
6.1.2.3	Renal Arteries.....	380
6.1.3	Normal Findings.....	380
6.1.3.1	Aorta.....	380
6.1.3.2	Visceral Arteries.....	380
6.1.3.3	Renal Arteries.....	382
6.1.4	Interpretation and Documentation.....	383
6.1.5	Clinical Role of Duplex Ultrasound.....	383
6.1.5.1	Aorta.....	383
6.1.5.2	Visceral Arteries.....	385
6.1.5.3	Renal Arteries.....	386
6.1.6	Measurement Parameters, Diagnostic Criteria, and Role of Ultrasound	387
6.1.6.1	Renal Arteries.....	387
6.1.6.1.1	Renal Artery Occlusion.....	392
6.1.6.1.2	Transplant Kidney	392
6.1.6.2	Visceral Arteries.....	394
6.1.6.3	Aorta.....	399
6.2	Visceral and Retroperitoneal Veins.....	404
6.2.1	Vascular Anatomy	404
6.2.1.1	Vena Cava.....	404
6.2.1.2	Renal Veins.....	404
6.2.1.3	Portal Venous System and Hepatic Veins.....	405
6.2.2	Examination Technique.....	405
6.2.2.1	Vena Cava.....	405
6.2.2.2	Renal Veins.....	406
6.2.2.3	Portal Vein and Superior Mesenteric Vein	406
6.2.3	Clinical Role of Duplex Ultrasound.....	407
6.2.3.1	Renal Veins.....	407
6.2.3.2	Portal Venous System.....	407
6.2.4	Normal Findings.....	408

6.2.4.1 Vena Cava and Renal Veins.....	408
6.2.4.2 Portal Venous System.....	408
6.2.5 Documentation	408
6.2.6 Abnormal Ultrasound Findings, Measurement Parameters, and Diagnostic Role	408
6.2.6.1 Vena Cava.....	408
6.2.6.2 Renal Veins.....	409
6.2.6.3 Superior Mesenteric Vein.....	410
6.2.6.4 Portal and Hepatic Veins.....	411
6.3 Atlas: Visceral and Retroperitoneal Vessels	415
7 Penile and Scrotal Vessels.....	473
7.1 Vascular Anatomy.....	473
7.1.1 Penile Vessels	473
7.1.2 Scrotal Vessels.....	473
7.2 Examination Technique	474
7.2.1 Erectile Dysfunction.....	474
7.2.2 Scrotal Vessels.....	475
7.3 Normal Findings	475
7.3.1 Penile Vessels	475
7.3.2 Scrotal Vessels.....	475
7.4 Documentation.....	475
7.5 Clinical Role of Duplex Ultrasound	476
7.5.1 Erectile Dysfunction.....	476
7.5.2 Acute Scrotum.....	476
7.5.3 Varicocele.....	477
7.6 Abnormal Findings: Role of Duplex Ultrasound Parameters.....	477
7.6.1 Erectile Dysfunction.....	477
7.6.2 Acute Scrotum.....	478
7.6.3 Varicocele.....	479
7.7 Atlas: Penile and Scrotal Vessels.....	480
References.....	485
Subject Index.....	513