

National Education Curriculum
Specialty Curricula
Vascular Technology

Vascular Technology

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Rationale: Accurate, appropriate, noninvasive vascular examinations require knowledge of sonography instrumentation, hemodynamics, and the pathophysiology and treatment of vascular disease. Applying this expertise to standardized diagnostic procedures, cross-referencing test results with established imaging techniques, and maintaining a consistent quality assurance process are necessary components for delivering high-quality patient care.

Section I: Fluid Dynamics

1. Define power, work, and energy
 2. Describe the differences between potential and kinetic energy
 3. Explain the importance of hydrostatic pressure in the human circulatory system
 4. Describe the relationship between volumetric flow and blood flow velocity
 5. Define capacitance and compliance
 6. Explain the impact of variations in fluid viscosity on blood flow
 7. Describe the components of Poiseuille's law and Bernoulli's principle
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I. FLUID DYNAMICS

A. General Description

1. Flow and related terms
2. Power, work and energy
3. Potential and kinetic energy
4. Hydrostatic pressure
5. Volumetric flow
6. Velocity
7. Capacitance
8. Compliance
9. Fluid viscosity

B. Description of Steady Flow

1. Rigid tube
2. Curved tube

C. Derivation of Equations

1. Resistance equation
2. Volumetric flow equation (continuity equation)
3. Simplified law of hemodynamics
4. Pressure/flow relationships
 - a. Poiseuille's law
 - b. Bernoulli's principle
 - i) Conservation of energy
 - ii) Bernoulli's equation
 - Equation with hydrostatic pressure term
 - Equation with heat term
 - c. Reynold's number
5. Relationship of equation components to each other

Section II: Physiology and Hemodynamics

1. Explain the relationship between pressure, flow and resistance
 2. Define and describe high-resistance and low-resistance flow profiles
 3. Relate the difference between steady and pulsatile flow
 4. Describe the changes in pulsatility of flow that occur with vasoconstriction and vasodilation
 5. Describe normal and abnormal flow profiles that occur in the arterial and venous systems
 6. Correlate flow profiles to pressure, flow and resistance
 7. Define systemic versus autoregulatory control of peripheral resistance
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II. PHYSIOLOGY AND HEMODYNAMICS (PULMONARY VERSUS SYSTEMIC)

A. Pressure and Flow Resistance

1. Left heart
 - a. Stroke volume
 - b. Cardiac output
 - i) Ejection fraction
 - ii) Pre-load and after-load
 - c. Cardiac cycle
 - d. Electrical conductivity
 - i) Relation to waveform morphology
2. Peripheral arterial system
 - a. Vessel sizes
 - b. Arterial resistance
 - i) High resistance
 - ii) Low resistance
 - c. Volume flow changes
 - i) Effects of vessel diameter
 - ii) Anatomy
 - iii) Pathology
 - iv) End-organ perfusion
 - d. Effective resistance in peripheral arterial system
 - i) Arteries
 - ii) Arterioles
 - iii) Capillaries
3. Peripheral venous system
 - a. Vessel diameter
 - b. Anatomy
 - c. Pathology
 - d. Effective resistance in the peripheral venous system
 - i) Vena cava
 - ii) Peripheral veins

iii) Venules

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4. Right and left heart
 - a. Effects on peripheral flow patterns
 - b. Pulmonary hemodynamics
 5. Cardiovascular system
 - a. Velocity versus cross-sectional area
 - b. Pressure changes in arterial system
 - i) Arteriolar regulation
 - ii) Change in waveforms
 - iii) Vasoconstriction/vasodilation
 - c. Pressure changes in venous system
 - i) Venous pressure
 - ii) Venous capacitance and static filling pressure
 - iii) Hydrostatic pressure
 - iv) Calf muscle pump
 - v) Respiratory related changes
 - vi) Venous resistance and transmural pressure
 - vii) Venous hypertension and edema
- B. Arterial Hemodynamics
1. Total energy
 - a. Potential
 - i) Hydrostatic
 - ii) Gravitational
 - b. Kinetic
 - c. Conservation of energy
 2. Energy gradient
 - a. Definition
 - b. Effects on flow
 - c. Effects of cardiac output and peripheral resistance
 3. Resistance
 - a. Effects of viscosity, friction, inertia
 - b. Blood in a non-newtonian fluid
 - c. Autoregulatory versus sympathetic
 4. Application of pressure/flow relationship
 - a. Poiseuille's law
 - i) Vessel length
 - ii) Vessel radius
 - b. Reynolds number
 5. Application of flow/pressure/velocity relationship

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- a. Bernoulli's principle
- 6. Steady versus pulsatile flow
- 7. Doppler flow profiles
 - a. Flow patterns
 - i) Laminar
 - Plug
 - Parabolic
 - ii) Disturbed
 - iii) Turbulent
 - b. Waveform morphology
 - i) Triphasic
 - ii) Monophasic
 - iii) Systolic upstroke
 - iv) Systolic deceleration
 - v) Diastolic component
 - c. Pressure pulse distortion
- 8. Effects of stenosis/occlusion on flow characteristics
 - a. Definition of hemodynamic significant stenosis
 - i) Flow versus pressure gradient
 - b. Direction of flow, turbulence, disturbed flow
 - c. Velocity acceleration/deceleration
 - d. Entrance/exit effects
 - e. Diameter reduction
 - f. Peripheral resistance
 - g. Collateral effects
 - h. Effects of exercise
 - i. Effects of occlusion
- C. Venous Hemodynamics
 - 1. Total energy
 - a. Potential
 - i) Hydrostatic
 - ii) Gravitational
 - b. Kinetic
 - c. Conservation of energy
 - 2. Venous resistance
 - 3. Pressure/volume relationships
 - a. Pressure gradient
 - b. Respirophasicity

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- c. Effects of calf muscle pump mechanism
 - i) Rest
 - ii) Contraction
 - iii) Relaxation
- d. Obstruction/resistance
- e. Venous insufficiency
 - i) Duration of reflux
 - ii) Venous hypertension
- f. Cardiac cycle
- 4. Effects of edema
- 5. Doppler flow profiles
 - a. Continuous/non-phasic
 - b. Phasic
 - i) Respiration
 - ii) Heartbeat
 - c. Pulsatility

Section III: Physical and Electrical Principles

1. Relate the difference between ultrasound energy and power
 2. Describe the types of graphic recording used in noninvasive vascular testing
 3. Explain methods for calibrating sonographic imaging systems and plethysmographic instruments
 4. Define alternating current (AC) versus direct current (DC) coupling, and explain the potential artifacts associated with inappropriate use
 5. Understand the most common units of measure associated with noninvasive vascular testing
 6. Describe the most common tests used for evaluation of tissue mechanics and pressure transmission in the peripheral venous and arterial systems
 7. List the types of plethysmography and pressure assessments used for evaluation of the peripheral arteries and veins
 8. Explain the relationship between Ohm's Law and hemodynamics
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III. PHYSICAL AND ELECTRICAL PRINCIPLES

A. General

1. Energy
2. Power
 - a. Relationship to flow dynamics
3. Ohm's Law
 - a. Description
 - b. Relationship to flow dynamics
4. Graphical recording
 - a. Sweep speed
5. Calibration and optimization
 - a. Spectral analysis
 - b. Continuous wave doppler
 - c. Plethysmographs
 - d. Strip chart
6. Zero-crossing detector
 - a. AC/DC coupling
7. Information displays
 - a. Monitors
 - b. Strip chart
8. Picture archiving communication system (PACS)
 - a. Digital imaging and communications in medicine (DICOM)

B. Units of Measure

1. Peak-systolic velocity (PSV)
2. End-diastolic velocity (EDV)
3. Acceleration Time
4. Pulsatility index (PI)
5. Resistive index (RI)
6. Frequency (kilo hertz, mega hertz)

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7. Centimeters or meters per second
8. Distance
9. Ratios
10. Flow volume
- C. Tissue Mechanics/Pressure Transmission
 1. Venous occlusion by limb positioning
 2. Superficial venous occlusion by tourniquets
 3. Volume changes by inflow/outflow
 4. Arterial occlusion by cuffs
- D. Plethysmography
 1. Volume displacement (pneumatic cuff)
 2. Photoplethysmography (PPG)
 - a. Venous
 - b. Arterial
- E. Pressure Measurements
 1. Palpatory
 2. Auscultatory
 3. Continuous wave (cw) Doppler (flow meter)
 4. Segmental pressure measurements
 - a. Cuff size artifact
- F. Other
 1. Skin temperature
 2. Transcutaneous oximetry (TCPO₂)
 3. Laser Doppler
- G. Oculopneumoplethysmography (Historical)
 1. OPG-Geeor OPG

Section IV: Cerebrovascular

1. Identify the vessels in the extracranial and intracranial cerebrovascular system
 2. Explain the effects of collateral flow on cerebral hemodynamics
 3. List the risk factors and mechanism for cerebrovascular disease
 4. Describe the evolution of atherosclerotic plaque
 5. Define transient ischemic attack (TIA), cerebrovascular accident (CVA/stroke) and vertebrobasilar insufficiency (VBI)
 6. Describe the capabilities, limitations, protocol/techniques, waveforms and diagnostic criteria for cerebrovascular circulation test procedures
 7. Describe the effects of stenosis and occlusion on flow characteristics in the extracranial cerebrovascular system
 8. Define standard contrast, digital subtraction, computed tomographic arteriography and magnetic resonance arteriography
 9. List the current treatment options for patients with cerebrovascular disease
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IV. Cerebrovascular

A. Anatomy

1. Aortic arch
 - a. Components
 - i) Ascending
 - ii) Transverse
 - iii) Descending
 - b. Major branches
 - i) Innominate (brachiocephalic) artery
 - ii) Left common carotid artery
 - iii) Left subclavian artery
 - c. Origination and termination of vessels
 - d. Relational anatomy of vessels
 - i) Principal arch anomalies
 - e. Collateral pathways
2. Carotid artery (extracranial)
 - a. Components
 - i) Common carotid artery (CCA)
 - ii) Carotid bulb
 - iii) Internal carotid artery (ICA)
 - Carotid siphon
 - Ophthalmic artery - 1st intracranial branch
 - iv) External carotid artery (ECA)
 - Superior thyroid artery
 - Ascending pharyngeal
 - Lingual
 - Occipital

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- Facial
 - Posterior auricular
 - Maxillary
 - Superficial temporal
 - b. Origination and termination of vessels
 - c. Relational anatomy
 - d. Collateral pathways
- 3. Vertebral artery
 - a. Segments
 - i) Pre-vertebral
 - ii) Cervical
 - iii) Horizontal (atlantic)
 - iv) Intracranial
 - b. Origination and termination
 - c. Relational anatomy
 - d. Collateral pathways
- B. Intracranial Circulation
 - 1. Components
 - a. Circle of Willis and contributing arteries
 - i) Terminal ICA
 - ii) Middle cerebral artery (MCA)
 - iii) Anterior cerebral artery (ACA)
 - iv) Anterior communicating artery (ACoA)
 - v) Posterior communicating arteries (PCoA)
 - vi) Posterior cerebral arteries (PCA)
 - vii) Basilar artery (Bas)
 - b. Terminal vertebral artery
 - c. Ophthalmic artery
 - 2. Origination and termination
 - 3. Relational anatomy
 - 4. Collateral pathways
- C. Congenital Variants
- D. Risk factors
 - 1. Controllable
 - a. Diabetes
 - b. Hyperlipidemia
 - c. Hypertension
 - d. Smoking

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- e. Atrial fibrillation
 - 2. Uncontrollable
 - a. Age
 - b. Gender
 - c. Family history
 - 3. Hypercoagulopathy
- E. Mechanisms of Disease
- 1. Atherosclerosis
 - a. Definition/characteristics
 - b. Common locations
 - c. Plaque evolution
 - d. Endothelial injury
 - e. Sub-endothelial deposit of lipids
 - f. Inflammatory response; smooth muscle cell proliferation
 - g. Plaque formation
 - h. Hemorrhage
 - i. Necrosis
 - j. Ulceration
 - k. Embolization/thrombosis
 - 2. Aneurysm
 - a. Definition/characteristics
 - b. True aneurysm
 - c. Fusiform
 - d. Saccular
 - e. Dissecting (arterial)
 - f. Pseudoaneurysm
 - g. Common location
 - 3. Thromboembolic events
 - a. Definition/characteristics
 - 4. Carotid body tumor
 - a. Definition/characteristics
 - 5. Fibromuscular dysplasia (FMD)
 - a. Definition/characteristics
 - b. Common locations
 - 6. Subclavian (vertebral) steal
 - a. Definition/characteristics
 - 7. Neointimal hyperplasia
 - a. Definition/characteristics

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- b. Common locations
- F. CVA (Stroke) Classifications
 - 1. Hemorrhagic
 - 2. Ischemic
 - 3. Lacunar
- G. Signs and Symptoms
 - 1. F.A.S.T.
 - a. Face drooping
 - b. Arm weakness (hemiparesis)
 - c. Speech difficulty (aphasia, dysphasia)
 - d. Time
 - 2. Transient symptoms
 - a. Transient ischemic attack (TIA)
 - b. Vertebrobasilar insufficiency (VBI)
 - 3. Non-localizing (non-focal) symptoms
- H. Physical Examination
 - 1. Palpation of pulses
 - a. Locations
 - b. Relevance
 - 2. Auscultation – bruits
 - a. Definition
 - b. Location
 - c. Relevance
 - 3. Bilateral brachial systolic pressure measurements
 - a. Indication
 - b. Relevance
- I. Noninvasive Test Procedures
 - 1. Indirect testing (historical and physiologic interest)
 - a. Periorbital doppler examination
 - b. Oculopneumoplethysmography (OPG)
 - 2. Direct testing/duplex sonography
 - a. Patient positioning
 - b. Choice of instrumentation/transducer frequencies
 - c. Examination protocol
 - d. Imaging and spectral Doppler techniques
 - e. 2-D interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics

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- iii) Measurements
 - Diameter
 - Area of stenosis
 - Intimal medial thickness (IMT)
 - Aneurysm size
- f. Spectral Doppler interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements
 - Peak-systolic velocity
 - ICA/CCA ratio
 - End-diastolic velocity
 - Pitfalls of measurements
 - Current diagnostic criteria
 - Resistive index
 - Pulsatility index
- g. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
 - Aliasing
 - Bruit
 - High and low resistive signal
- h. Capabilities
- i. Limitations
- 3. Intraoperative duplex sonography
 - a. Indications
 - b. Monitoring
 - c. Limitations
- 4. Transcranial Doppler (TCD)/transcranial imaging (TCI) examination
 - a. Patient positioning
 - b. Choice of instrumentation/transducer frequency
 - i) Imaging
 - ii) Non-imaging
 - c. Examination protocol
 - i) Acoustic windows
 - ii) Vessel depth
 - iii) Signal traceability

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- iv) Sample volume size
 - v) Transmit frequency/power
 - d. Imaging and spectral Doppler techniques
 - e. Spectral Doppler interpretation
 - i) Normal characteristics
 - Flow direction
 - Flow pattern
 - Velocity ranges
 - ii) Abnormal characteristics
 - iii) Measurements
 - Maximum of the mean velocity
 - Peak-systolic velocity
 - End-diastolic velocity
 - MCA/ICA ratio
 - Pulsatility index
 - Resistive index
 - Pitfalls of measurements
 - Embolic showers
 - High intensity transient signal (HITS)
 - f. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
 - g. Capabilities
 - i) Current clinical use
 - ii) Monitoring
 - h. Limitations
- J. Continuous Wave (CW) Doppler
 - 1. Patient positioning
 - 2. Examination protocol/technique
 - 3. Interpretation
 - a. Normal characteristics
 - b. Abnormal characteristics
 - c. Measurements
- K. Correlative and/or Prior Imaging
 - 1. Conventional arteriography
 - a. Interpretation
 - i) Stenosis

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- ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
- 2. Digital subtraction arteriography (DSA)
 - a. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
- 3. Computed tomography arteriography (CTA)
 - a. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
- 4. Magnetic resonance arteriography (MRA)
 - a. Current clinical use
 - b. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - c. Limitations
- L. Treatment
 - 1. Indications
 - 2. Medical control and reduction of risk factors
 - a. Lifestyle
 - b. Pharmacologic control
 - i) Hypertension
 - ii) Cholesterol
 - iii) Clotting factors
 - 3. Endovascular
 - a. Thrombolytic therapy
 - b. Percutaneous transluminal angioplasty (PTA)
 - c. Carotid angioplasty and stenting (CAS)
 - 4. Surgical
 - a. Endarterectomy
 - b. Bypass graft
 - 5. Acute thrombolytic therapy

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Section V: Peripheral Venous

1. Identify the central, upper and lower extremity deep and superficial veins, and list the major perforating veins in the lower extremity
 2. Describe the function of vein valve leaflets in venous physiology in the normal patient and the patient with venous insufficiency
 3. List the components of Virchow's Triad, and relate how these impact venous pathophysiology
 4. Describe risk factors for venous thrombosis
 5. Relate the mechanisms of disease associated with acute and chronic deep vein thrombosis, superficial thrombophlebitis, venous insufficiency and pulmonary embolism
 6. Define the clinical signs associated with acute and chronic deep vein thrombosis and superficial thrombophlebitis
 7. Describe the role of the calf muscle pump in venous physiology
 8. Relate the pathological findings associated with venous stasis and venous insufficiency
 9. Describe the capabilities, limitations, patient positioning, protocol/techniques and diagnostic criteria for the following venous examinations: duplex sonography, color flow imaging and venous refill plethysmography
 10. Define correlative imaging technologies
 11. List the current treatment options for patients with deep vein thrombosis or superficial thrombophlebitis
 12. Describe the CEAP classification for chronic venous insufficiency
-

V. PERIPHERAL VENOUS

A. Anatomy

1. Upper extremity deep veins
 - a. Components
 - i) Deep digital and deep palmar
 - ii) Radial and ulnar
 - iii) Brachial
 - iv) Axillary
 - v) Subclavian
 - Significance of thoracic outlet anatomy
 - vi) Brachiocephalic (innominate)
 - vii) Superior vena cava (SVC)
 - viii) Neck – Internal jugular, external jugular
 - b. Origination and termination of vessels
 - c. Anatomic anomalies
 - d. Relational anatomy of vessels
 - e. Collateral pathways
2. Upper extremity superficial veins
 - a. Components
 - i) Cephalic
 - ii) Basilic
 - iii) Median cubital
 - b. Origination and termination of vessels
 - c. Anatomic anomalies
 - d. Relational anatomy of vessels

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- e. Collateral pathways
- 3. Lower extremity deep veins
 - a. Components
 - i) Deep digital and metatarsal
 - ii) Calf veins
 - Soleal veins
 - Gastrocnemius (sural) veins
 - Tibioperoneal trunk
 - Peroneal
 - Posterior tibial
 - Anterior tibial
 - iii) Popliteal
 - iv) Femoral (FV)
 - v) Deep femoral (profunda femoris)
 - vi) Common femoral (CFV)
 - vii) External and internal iliac (hypogastric)
 - viii) Common iliac
 - ix) Inferior vena cava (IVC)
 - b. Origination and termination of vessels
 - c. Anatomic anomalies
 - d. Relational anatomy of vessels
 - i) Significance of left common iliac vein location
 - e. Collateral pathways
- 4. Lower extremity superficial veins
 - a. Components
 - i) Great saphenous
 - ii) Small saphenous
 - b. Origination and termination of vessels
 - c. Anatomic anomalies
 - d. Relational anatomy of vessels
 - e. Collateral pathways
- 5. Lower extremity perforating veins
 - a. Origination and termination of vessels
- 6. Central venous system
 - a. Components
 - i) Vena cava
 - Superior vena cava (SVC)
 - Inferior vena cava (IVC)

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- ii) Portal, hepatic, renal and mesenteric
 - b. Origination and termination of vessels
 - c. Anatomic anomalies
 - d. Relational anatomy of vessels
 - e. Collateral pathways
- 7. Vein walls and valve leaflets
 - a. Intima
 - b. Media
 - c. Adventitia
 - d. Valve leaflets
 - i) Location and number of valves
 - ii) Relationship with pathophysiology of DVT
- B. Risk Factors
 - 1. Pre-disposing
 - a. Age
 - b. Cancer
 - c. Prolonged bed rest or inactivity
 - d. Prior episode of DVT
 - e. Trauma
 - f. Hormones
 - g. Paraplegia
 - h. Surgery
 - i. Pregnancy
 - j. Thrombophilias
 - 2. Virchow's triad
 - a. Stasis
 - b. Hypercoagulability
 - c. Vessel wall injury
- C. Mechanisms of Disease
 - 1. Acute deep venous thrombosis
 - 2. Chronic deep venous thrombosis
 - a. Post-thrombotic syndrome
 - 3. Chronic venous insufficiency
 - a. Valvular incompetence
 - b. Outflow obstruction
 - c. Iliac vein compression syndrome
 - i) Formerly referred to as May Thurner syndrome
 - d. Stasis ulceration

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- e. Ambulatory venous hypertension
 - 4. Venous aneurysm
 - 5. Varicose veins
 - a. Primary venous insufficiency
 - b. Secondary venous insufficiency
 - 6. Congenital
 - a. Absence of valves
 - b. Hypercoagulability
 - 7. Pulmonary embolism (PE)
 - D. Signs and Symptoms
 - 1. Acute deep venous thrombosis
 - a. Phlegmasia alba dolens
 - b. Phlegmasia cerulea dolens
 - 2. Chronic postthrombotic change
 - 3. Venous ulceration/stasis ulcers
 - a. Chronic venous insufficiency (CVI)
 - i) Clinical etiologic anatomic pathologic classification (CEAP)
 - Venous ulcer, venous stasis
- E. Noninvasive Test Procedures for Upper and Lower Extremities Venous Thrombosis
 - 1. Duplex imaging
 - a. Patient positioning
 - b. Choice of instrument/transducer frequencies
 - c. Examination protocol
 - d. Imaging and spectral Doppler techniques
 - e. 2-D interpretation
 - i) Thrombus characteristics
 - Acute
 - Chronic
 - ii) Normal characteristics
 - iii) Abnormal characteristics
 - f. Spectral Doppler interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Flow characteristics
 - g. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics

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- iv) Recanalization
 - v) Collateralization
 - h. Capabilities
 - i. Limitations
 - 2. Non-imaging (historical interest)
 - a. CW Doppler venous examination
 - b. Strain gauge plethysmography (SPG)
 - c. Impedance plethysmography (IPG)
- F. Noninvasive Test Procedures for Chronic Venous Insufficiency
- 1. Duplex imaging/color flow imaging
 - a. Identification of valvular incompetence
 - i) Spectral Doppler
 - ii) Color Doppler
 - iii) Duration of retrograde flow
 - iv) Deep versus superficial venous incompetence
 - b. Identification of perforator incompetence
 - i) Spectral Doppler
 - ii) Color Doppler
 - iii) Perforator measurement
 - c. Venous obstruction
 - d. Assistance during and after radiofrequency/laser ablation procedures
 - 2. Reflux plethysmography
 - a. Photoplethysmography (PPG)
 - i) Venous refill time (VRT)
 - Tourniquet application/location
 - b. Air plethysmography
- G. CEAP Classification
- 1. Classification system for reporting and treating the diverse manifestations of chronic venous disorders
 - a. Clinical
 - i) Visual changes seen on the extremity
 - b. Etiology
 - i) Congenital
 - ii) Primary
 - iii) Secondary
 - c. Anatomy
 - i) Superficial veins
 - ii) Deep veins

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- iii) Perforating veins
 - d. Pathophysiology
 - i) Reflux
 - ii) Obstruction
- H. Correlative and/or Prior Imaging
 - 1. Conventional venography
 - a. Ascending
 - b. Descending
 - 2. Magnetic resonance venography (MRV)
 - 3. Computed tomography venography (CTV)
- I. Other Diagnostic Testing
 - 1. Ventilation-perfusion lung scan
 - 2. D-dimer assay
 - 3. CTA
- J. Treatment
 - 1. Indications for treatment
 - 2. Anticoagulation
 - 3. Thrombolytic therapy
 - a. Systemic
 - b. Catheter-directed
 - 4. Vena caval filters
 - 5. Stent placement for iliac vein compression syndrome
 - 6. Compression stockings
 - 7. Surgery
 - a. Ligation of perforating veins
 - b. Stripping or local excision of varicosities/phlebectomy
 - c. Sclerotherapy
 - 8. Radiofrequency/laser ablation of incompetent saphenous veins
 - a. Sonography guidance for and/or endovenous laser ablation procedures for incompetent saphenous veins
 - 9. Vein mapping for arterial and AV fistula procedures
 - a. Upper extremity
 - b. Lower extremity
 - c. Endoscopic vein surgery

Section VI: Peripheral Arterial

1. Identify the major arteries of the upper and lower extremities and the branches of the abdominal aorta
 2. Differentiate between arterial and venous wall anatomy at the microscopic level
 3. List the risk factors and mechanisms for arterial disease
 4. List the most common sites for arterial disease in the peripheral arterial system
 5. Differentiate fusiform, saccular, and dissecting aneurysms
 6. List common nonatherosclerotic vascular disorders
 7. Differentiate the symptoms of acute arterial occlusion and chronic arterial occlusive disease
 8. Relate the difference between primary and secondary Raynaud's syndrome
 9. Describe the capabilities, limitations, protocols/techniques and diagnostic criteria for noninvasive peripheral arterial test procedures
 10. Define correlative imaging techniques
 11. Describe the current treatment options for patients with peripheral arterial disease
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VI. PERIPHERAL ARTERIAL

A. Anatomy

1. Upper extremity arteries
 - a. Components
 - i) Innominate (brachiocephalic)
 - ii) Subclavian
 - iii) Axillary
 - iv) Brachial
 - v) Radial
 - vi) Ulnar
 - vii) Interosseous
 - viii) Palmar (volar) arches
 - Deep
 - Superficial
 - ix) Digital
2. Abdominal aorta
 - a. Functional division
 - i) Supra-renal
 - ii) Infra-renal
 - b. Branches
 - i) Phrenic
 - ii) Celiac
 - iii) Superior mesenteric (SMA)
 - iv) Renal
 - v) Gonadal
 - vi) Inferior mesenteric (IMA)
 - vii) Lumbar
3. Lower extremity arteries

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- a. Components
 - i) Common iliac
 - ii) External iliac
 - iii) Internal iliac (hypogastric)
 - iv) Common femoral (CFA)
 - v) Superficial femoral (SFA)
 - vi) Deep femoral (profunda femoris)
 - vii) Popliteal
 - viii) Tibioperoneal trunk
 - ix) Anterior tibial
 - x) Posterior tibial
 - xi) Peroneal
 - xii) Plantar arteries
 - xiii) Digital arteries
 - 4. Microscopic anatomy of the arterial wall, capillaries, arterioles
- B. Risk Factors
- 1. Controllable risk factors
 - a. Diabetes
 - b. Hypertension
 - c. Hyperlipidemia
 - d. Smoking
 - 2. Uncontrollable risk factors
 - a. Age
 - b. Gender
 - c. Family history
 - d. Thrombophilia
- C. Mechanisms of Disease
- 1. Atherosclerosis
 - a. Plaque evolution
 - 2. Embolization
 - 3. Aneurysm
 - a. Fusiform
 - b. Saccular
 - c. Dissecting (arterial)
 - d. Pseudoaneurysm
 - 4. Nonatherosclerotic lesions
 - a. Arteritis
 - i) Types

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- ii) Common locations
 - b. Vasospastic disorders
 - i) Raynaud's syndrome
 - Primary – Raynaud's disease
 - Secondary – Raynaud's phenomenon
 - c. Aortic coarctation
 - i) Etiology and characteristics
 - d. Entrapment syndromes
 - i) Popliteal artery entrapment
 - ii) Thoracic outlet syndrome (TOS)
 - e. Popliteal adventitial cystic disease
- D. Signs and Symptoms
 - 1. Chronic occlusive disease
 - a. Claudication
 - b. Ischemic rest pain
 - c. Trophic changes
 - i) Gangrene
 - ii) Ulcers
 - 2. Acute arterial occlusion
 - a. Embolic
 - b. Thrombotic
 - c. Trauma
 - d. Six P's
 - i) Pain
 - ii) Pallor
 - iii) Pulselessness
 - iv) Paresthesia
 - v) Paralysis
 - vi) Poikilothermia
 - 3. Vasospastic disorders
 - a. Digital cold sensitivity
 - 4. Physical examination
 - a. Skin (dermal) changes
 - i) Color
 - ii) Temperature
 - iii) Thickened nails; scaly, thin, transparent-appearing skin; loss of hair
 - b. Palpation of pulses
 - c. Auscultation of pulses

Vascular Technology

E. Noninvasive Test Procedures

1. Indirect (physiologic) testing

a. Segmental systolic pressure measurements

- i) Rationale
- ii) Cuff sizes
- iii) Extremity
 - 3-cuff versus 4-cuff techniques
 - Advantages and disadvantages

iv) Digital

v) Penile

vi) Examination protocols

vii) Interpretation criteria of pressures

viii) Normal pressure gradients

ix) Abnormal pressure gradients

x) Capabilities

xi) Limitations

b. Constant-load treadmill exercise testing

i) Rationale

ii) Examination protocol

- Placement of blood pressure cuffs
- Walking speed and elevation
- Claudication distance
- Post-exercise ankle and arm pressure measurements order and timing

iii) Interpretation of post-exercise ankle pressure response

- Normal
- Abnormal
 - Duration of reduced pressures (time to reconstitution of pressure)

c. Reactive hyperemia

i) Rationale

ii) Examination protocol

- Cuff sizes
- Placement of pressure cuffs
- Cuff pressure
- Duration of cuff inflation

iii) Interpretation of post-inflation pressure response

- Normal
- Abnormal
 - Duration of reduced pressure (time to reconstitution of pressure)

Vascular Technology

- iv) Capabilities
- v) Limitations
- d. Plethysmography
 - i) Pulse volume recording
 - Rationale
 - Patient positioning
 - Examination protocol
 - Cuff sizes and placement
 - Pressure and volume calibration
 - Interpretation of plethysmographic waveforms
 - Normal
 - Abnormal
 - Capabilities
 - Location of segmental flow-reducing obstruction
 - Assessment of collateral flow
 - Limitations (potential sources of error)
 - Inappropriate cuff size/calibration
 - Obesity
 - Edema
 - Resting muscle tremors (waveform artifact)
 - ii) Photoplethysmography (PPG)
 - Rationale
 - Clinical uses
 - Digital pressures and waveforms
 - Assessment of skin perfusion (wound healing potential)
 - Digital cold sensitivity testing
 - Examination protocol
 - Sensor placement
 - Interpretation of PPG waveforms
 - Normal
 - Abnormal
 - Capabilities
 - Arterial pressures
 - Assessment of skin perfusion
 - Limitations
 - Qualitative assessment only
 - Temperature
 - Vasodilation/vasoconstriction

Vascular Technology

2. Direct testing
 - a. Continuous wave (CW) Doppler evaluation
 - i) Analog waveforms
 - Qualitative interpretation
 - Quantitative interpretation
 - Pulsatility index
 - Acceleration time
 - b. Duplex imaging/color flow imaging
 - i) Patient positioning
 - ii) Choice of instrumentation/transducer frequencies
 - iii) Examination protocol
 - iv) Imaging and spectral Doppler techniques
 - v) 2-D Interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Diameter versus area
 - Lesion length
 - vi) Spectral Doppler interpretation
 - Normal flow characteristics
 - Native arteries
 - Bypass grafts/stents
 - Abnormal flow characteristics
 - Stenosis
 - Occlusion
 - Bypass grafts/stents
 - Aneurysms
 - Pseudoaneurysms
 - Trauma
 - Qualitative interpretation
 - Phasicity
 - Spectral broadening
 - Turbulence
 - Quantitative interpretation
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratio
 - Pulsatility index

Vascular Technology

- Resistive index
- Acceleration time
- Acceleration index

- Pitfalls of measurements

vii) Color Doppler interpretation

- Presence/absence of flow
- Direction of flow
- Flow characteristics

viii) Capabilities

ix) Limitations

F. Correlative and/or Prior Imaging

1. Conventional arteriography

- a. Interpretation
- b. Stenosis
- c. Occlusion
- d. Collaterals/intracranial cross-filling
- e. Limitations

2. Digital subtraction angiography

- a. Interpretation
- b. Stenosis
- c. Occlusion
- d. Collaterals/intracranial cross-filling
- e. Limitations

3. Computed tomographic arteriography

- a. Interpretation
- b. Stenosis
- c. Occlusion
- d. Collaterals/intracranial cross-filling
- e. Limitations

4. Magnetic resonance angiography

- a. Current clinical use
- b. Interpretation
- c. Stenosis
- d. Occlusion
- e. Collaterals/intracranial cross-filling
- f. Limitations

G. Treatment

1. Indications for treatment

Vascular Technology

2. Medical
 - a. Control and reduction of risk factors
 - b. Exercise
 - c. Pharmacologic
 - d. Blood pressure
 - e. Cholesterol
 - f. Clotting factors
 - g. Drug therapy
3. Surgical
 - a. Thrombectomy
 - b. Embolectomy
 - c. Endarterectomy
 - d. Bypass graft
 - i) In situ saphenous
 - ii) Reversed saphenous
 - iii) Non-reversed transposed saphenous
 - iv) Prosthetic
4. Cryo-preserved grafts
 - a. Anastomoses
 - b. End-to-side
 - c. End-to-end
5. Interposition graft
 - a. Side-to-side
6. Amputation
 - a. Fasciotomy
 - b. Split-thickness skin grafts
7. Endovascular
 - a. Percutaneous transluminal angioplasty (PTA)
 - b. Stent
 - c. Endograft (covered stent)
8. Athrectomy
9. Compression/thrombin injection
10. Pseudoaneurysm repair

Section VII: Abdominal/Visceral

1. Identify the arteries and veins of the abdomen and list the major branches of the abdominal aorta
 2. List the common risk factors for abdominal arterial and venous disorders
 3. Describe the mechanisms of disease for renovascular hypertension, renal fibromuscular dysplasia, abdominal aortic aneurysm, portal hypertension and acute and chronic mesenteric ischemia
 4. Describe the variations in vascular resistance in the mesenteric arterial system during fasting and post-prandial states
 5. Relate the clinical presentation of patients with abdominal aortic aneurysm, portal hypertension, and chronic mesenteric ischemia
 6. Describe the capabilities, limitations, patient positioning, protocols/techniques, and current diagnostic criteria for duplex sonography of the abdominal aorta, renal and mesenteric arteries and the hepatoportal system
 7. Differentiate normal and abnormal Doppler spectral waveforms from the hepatic and portal veins and the inferior vena cava
 8. Describe the correlating imaging modalities used for confirmation of abdominal vascular disease
 9. Describe the current treatment options for patients with renovascular hypertension, mesenteric ischemia, abdominal aortic aneurysm and portal hypertension
-

VII. ABDOMINAL/VISCERAL

A. Anatomy

1. Abdominal pelvic arterial
 - a. Components
 - i) Aorta
 - ii) Celiac artery (trunk, axis)
 - Hepatic arteries
 - Splenic artery
 - Left gastric
 - iii) Superior mesenteric artery (SMA)
 - iv) Renal arteries
 - v) Inferior mesenteric artery (IMA)
 - vi) Gonadal arteries
 - vii) Iliac arteries
2. Abdominal pelvic venous
 - a. Components
 - i) Iliac veins
 - ii) Gonadal veins
 - iii) Inferior mesenteric vein (IMV)
 - iv) Renal veins
 - v) Splenic vein
 - vi) Superior mesenteric vein (SMV)
 - vii) Portal vein tributaries
 - Superior mesenteric vein
 - Splenic vein
 - Inferior mesenteric vein

Vascular Technology

viii) Hepatic veins

ix) Inferior vena cava (IVC)

B. Congenital Variants

C. Risk Factors

1. Arterial

- a. Diabetes
- b. Hypertension
- c. Hyperlipidemia
- d. Smoking
- e. Atrial fibrillation

2. Venous

- a. Prior thrombosis
- b. Malignancy
- c. Liver disease

D. Mechanisms of Disease

1. Renovascular hypertension

- a. Consistent clinical features
 - i) Hypertension
 - ii) Renal artery stenosis/occlusion/fibromuscular dysplasia
 - iii) Renal ischemia
- b. Etiology
 - i) Atherosclerosis
 - ii) Fibromuscular dysplasia
 - iii) Arteritis
 - iv) Post-irradiation fibrosis
 - v) Neurofibromatosis
 - vi) Thrombosis/embolism

2. Mesenteric angina/ischemia

- a. Chronic celiac, SMA, IMA stenosis or occlusion
 - i) Consistent clinical features
 - Post-prandial pain
 - “Fear of food” syndrome
 - Weight loss
 - ii) Etiology
 - Atherosclerosis
 - Thrombosis/embolism
 - Median arcuate ligament syndrome
- b. Acute mesenteric ischemia

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- i) Consistent clinical features
 - Insidious onset acute, severe abdominal pain out of proportion to physical findings.
 - Result of delayed diagnosis
 - Potential for catastrophic gastrointestinal ischemia
 - Extremely high mortality rate, even with treatment
- ii) Etiology
 - Embolism
 - Thrombosis
- 3. Portal hypertension
 - a. Portal splenic vein thrombosis
 - b. Cirrhosis
 - c. Budd-chiari syndrome
- 4. Abdominal aortic aneurysm
 - a. Size
 - b. Location
 - c. Classification
 - i) Fusiform
 - ii) Saccular
 - iii) Dissecting
 - iv) Mycotic
 - d. Etiology
 - i) Atherosclerosis
 - ii) Aging
 - iii) Infection (mycotic)
 - iv) Inflammatory aneurysm: distinct clinical scenario
 - v) Trauma
 - vi) Congenital anomalies
 - Ehlers-Danlos syndrome
 - Marfan's syndrome
 - Others
 - vii) Medial degeneration
 - viii) Arteritis
- 5. Visceral venous aneurysm(s)
 - a. Portal vein
 - b. IVC
- E. Signs and Symptoms
 - 1. Arterial

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- a. Acute mesenteric ischemia
 - i) Abrupt onset of severe abdominal pain
 - ii) Gastrointestinal tissue injury
 - b. Chronic mesenteric ischemia
 - i) Triad of symptoms
 - c. Renal
 - i) Renovascular hypertension
 - ii) Renal artery stenosis/occlusion
 - iii) Renal ischemia
 - d. Aneurysm
 - i) Incidental finding
 - ii) “Pulsatile abdominal mass”
 - iii) Abdominal or back pain
 - iv) Embolization/blue toe syndrome
 - Digital arteries
 - End-arterial occlusion
 - v) Rupture
 - Contained retroperitoneal
 - Free rupture
2. Venous
- a. Portal
 - i) Portal hypertension
 - Cirrhosis
 - GI bleed
 - Ascites
 - Jaundice
 - b. Hepatic
 - i) Budd-Chiari syndrome
 - ii) Primary vs. secondary
 - Portal hypertension
 - Hepatomegaly
 - Ascites
 - Abdominal pain
 - c. IVC
 - i) Lower extremity edema
 - Venous claudication
 - Stasis ulceration
 - d. Pelvis

Vascular Technology

- i) Pelvic congestion syndrome (PCS)

F. Noninvasive Test Procedures

- 1. Direct-duplex imaging/color flow imaging
 - a. Patient positioning
 - b. Examination protocol
 - c. Assessment of organs as related to the vascular structure
 - i) Gallbladder
 - ii) Liver
 - iii) Pancreas
 - iv) Renals
 - v) Spleen
 - d. Imaging and spectral Doppler techniques
 - i) Aorta
 - ii) Celiac, splenic, and hepatic arteries
 - iii) Mesenteric arteries
 - iv) Renal arteries
 - v) IVC
 - vi) Hepatic veins
 - vii) Portal, splenic, and mesenteric veins
 - viii) Renal veins
 - e. 2-D interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements
 - Diameter versus area reduction
 - f. Spectral Doppler interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratio
 - Pulsatility index
 - Resistive index
 - Pitfalls of measurements
 - g. Waveform analysis
 - i) Triphasic
 - ii) Biphasic

Vascular Technology

- iii) Monophasic
 - iv) Continuous, non-phasic
 - v) Pulsatile
 - h. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
 - i. Capabilities
 - j. Limitations
- G. Correlative and/or Prior Imaging
 - 1. Contrast-enhanced ultrasound (CEUS)
 - a. Interpretation
 - i) Endovascular aneurysm repair assessment
 - 2. Conventional arteriography
 - a. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
 - 3. Digital subtraction arteriography
 - a. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
 - 4. Computed tomographic arteriography
 - a. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - b. Limitations
 - 5. Magnetic resonance arteriography (MRA)
 - a. Current clinical use
 - b. Interpretation
 - i) Stenosis
 - ii) Occlusion
 - iii) Collaterals/intracranial cross-filling
 - c. Limitations

Vascular Technology

H. Treatment

1. Indications for treatment
2. Medical
 - a. Antihypertensives; beta blockers
 - b. Anticoagulation
3. Surgical
 - a. Bypass graft
 - b. Endarterectomy
4. Endovascular
 - a. Endovascular aneurysm repair aortic endograft (EVAR or stent graft) fenestrated and branched endovascular aortic prostheses (FEVAR/BEVAR)
 - b. Angioplasty/stent
 - c. IVC interruption device (filter)
 - d. Transjugular intrahepatic portosystemic shunt (TIPS)

Section VIII: Miscellaneous Conditions/Tests

1. Describe the protocols and techniques used for preoperative mapping of the extremity veins, and the radial, internal mammary and epigastric arteries
 2. Differentiate the anatomy and blood flow patterns of pseudoaneurysms and arteriovenous fistulae
 3. Relate the technical protocols for assessment of dialysis access grafts and fistulae
 4. Detail the sonographic evaluation of liver, pancreas, and renal transplants
 5. Describe the tests, procedures, and modalities used for evaluation of vasculogenic impotence
 6. Relate the noninvasive vascular test procedures and provocative maneuvers used for detection of thoracic outlet syndrome
 7. Describe the capabilities and limitations of duplex sonography for identification of temporal arteritis
 8. Define the test procedures used for evaluation of arterial injury
 9. Differentiate the signs and symptoms of congenital and acquired lymphedema and deep vein thrombosis
-

VIII. MISCELLANEOUS CONDITIONS/TESTS

A. Preoperative Venous and Arterial Mapping

1. Potential vessels for use as bypass conduits
 - a. Saphenous veins, cephalic and basilic veins
 - b. Radial artery
 - c. Internal mammary artery
 - d. Epigastric artery
2. Patient positioning
3. Examination protocols
4. Imaging and spectral Doppler techniques
5. 2-D interpretation
 - a. Normal characteristics
 - b. Abnormal characteristics
 - c. Measurements
 - i) Diameter
 - ii) Length
6. Spectral Doppler interpretation
 - a. Normal characteristics
 - b. Abnormal characteristics
 - c. Measurements/waveform analysis
 - i) Venous
 - Phasic versus non-phasic
 - ii) Arterial
 - Triphasic/biphasic/monophasic
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratios
 - d. Pitfalls of measurements
7. Color Doppler interpretation

Vascular Technology

- a. Presence/absence of flow
- b. Direction of flow
- c. Flow characteristics
8. Capabilities
9. Limitations
- B. Pseudoaneurysm/Arteriovenous Fistula
 1. Pseudoaneurysm
 - a. Direct-duplex scanning and color flow imaging
 - i) Patient positioning
 - ii) Examination protocols
 - iii) Imaging and spectral Doppler techniques
 - Sonography-guided probe compression repair
 - Sonography-guided thrombin injection repair
 - iv) 2-D interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Multilobar
 - Concomitant arteriovenous fistula
 - Measurements
 - Pseudoaneurysm diameter
 - Neck length and diameter
 - v) Spectral Doppler interpretation
 - Characteristics of flow
 - Measurements/waveform analysis
 - Characteristic to-fro (bidirectional) Doppler signal
 - Proximal and distal arterial flow signals
 - Pitfalls of measurements
 - vi) Color Doppler interpretation
 - Presence/absence of flow
 - Direction of flow
 - Flow characteristics
 - vii) Capabilities
 - viii) Limitations
 2. Arteriovenous fistula
 - a. Classification
 - i) Traumatic
 - ii) Congenital
 - b. Noninvasive test procedure

Vascular Technology

- i) Direct-duplex scanning and color flow imaging
 - c. Patient positioning
 - d. Examination protocols
 - e. Imaging and spectral Doppler techniques
 - f. 2-D interpretation
 - i) Characteristics
 - ii) Measurements
 - Location
 - Diameter/length
 - g. Spectral Doppler interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements/waveform analysis
 - Characteristic low resistance Doppler signal
 - Proximal and distal venous flow signals
 - h. Pitfalls of measurements
 - i. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
 - j. Capabilities
 - k. Limitations
3. Dialysis access
- a. Noninvasive test procedure
 - i) Duplex scanning and color flow imaging
 - Patient positioning
 - Examination protocols
 - Pre-operative mapping of inflow and outflow vessels
 - Dialysis fistulae
 - ~ Brescia-Upper arm
 - ~ Lower arm
 - ~ Groin
 - Dialysis grafts
 - ~ Straight
 - ~ Looped
 - Catheters
 - ~ Short-term access
 - Imaging and spectral Doppler techniques

Vascular Technology

- 2-D interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
- Spectral Doppler interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements/waveform analysis
 - ~ Peak-systolic velocity
 - ~ End-diastolic velocity
 - ~ Velocity ratios
 - ~ Flow volume
- Pitfalls of measurements
- Color Doppler interpretation
 - Presence/absence of flow
 - Direction of flow
 - Flow characteristics
- Capabilities
- Limitations

C. Organ Transplants

1. Types
 - a. Kidney
 - b. Liver
 - c. Pancreas
2. Noninvasive test procedures
 - a. Patient positioning
 - b. Examination protocols
 - c. Imaging and spectral Doppler techniques
 - d. 2-D interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements
 - Length
 - Width
 - e. Spectral Doppler interpretation
 - i) Normal characteristics
 - ii) Abnormal characteristics
 - iii) Measurements

Vascular Technology

- Peak-systolic velocity
- End-diastolic velocity
- Velocity ratios
- Resistive index
- Pulsatility index
- Pitfalls of measurements
- f. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
- g. Capabilities
- h. Limitations
- D. Impotence Testing
 - 1. Noninvasive test procedures
 - a. Indirect
 - i) Pressures
 - Penile-brachial index
 - b. Direct - duplex sonography and color flow imaging
 - i) Patient positioning
 - ii) Examination protocols
 - iii) Imaging and spectral Doppler techniques
 - Techniques for cavernosal artery injection
 - Papaverine
 - Prostaglandin
 - iv) 2-D interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Pre- and post-injection
 - Anterior-posterior dimensions
 - ~ Cavernosal arteries
 - ~ Deep dorsal vein
 - v) Spectral Doppler interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Post-injection timing

Vascular Technology

- Peak-systolic velocity
 - ~ Pre-injection
 - ~ Post-injection
 - End-diastolic velocity
 - ~ Pre-injection
 - ~ Post-injection
 - Duration of erection
 - Pitfalls of measurements
 - c. Color Doppler interpretation
 - i) Presence/absence of flow
 - ii) Direction of flow
 - iii) Flow characteristics
 - d. Capabilities
 - e. Limitations
- E. Thoracic Outlet Syndrome (TOS) Evaluation
 - 1. Noninvasive test procedures
 - a. Indirect
 - i) Plethysmography
 - Pulse volume recording
 - Digital photoplethysmography
 - ii) Upper extremity systolic pressures
 - iii) Patient positioning
 - iv) Examination protocol
 - Provocative maneuvers
 - v) Techniques for indirect assessment
 - Arterial inflow
 - Arterial outflow
 - vi) Interpretation of waveforms and pressures
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Qualitative
 - Quantitative
 - b. Direct-duplex sonography with color flow imaging
 - i) Patient positioning
 - ii) Examination protocols
 - iii) Imaging and spectral Doppler techniques
 - iv) 2-D interpretation

Vascular Technology

- Normal characteristics
- Abnormal characteristics
- Measurements
 - Arterial/venous diameter proximal to thoracic outlet
 - Arterial/venous diameter distal to thoracic outlet
- v) Spectral Doppler interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratio
 - Pitfalls of measurements
 - Color doppler interpretation
 - Presence/absence of flow
 - Direction of flow
 - Flow characteristics
 - Capabilities
 - Limitations

F. Vascular Arteritis

1. Classification
 - a. Temporal arteritis
 - b. Takayasu's arteritis
2. Noninvasive test procedures
 - a. Duplex sonography with color flow imaging
 - i) Patient positioning
 - ii) Examination protocol
 - iii) Imaging and spectral Doppler techniques
 - iv) 2-D Interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Halo sign
 - Macaroni sign
 - Measurements
 - Anterior-posterior diameter
 - Transverse diameter
 - Residual lumen diameter
 - v) Spectral Doppler interpretation

Vascular Technology

- Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratio
 - Pitfalls of measurements
 - vi) Color Doppler interpretation
 - Presence/absence of flow
 - Direction of flow
 - Flow characteristics
 - vii) Capabilities
 - viii) Limitations
- G. Trauma/Arterial Injury
1. Noninvasive test procedures
 - a. Indirect testing
 - i) CW Doppler
 - ii) Plethysmography
 - b. Direct testing - duplex sonography with color flow imaging
 - i) Patient positioning
 - ii) Choice of instrumentation and transducer frequencies
 - iii) Examination protocol
 - iv) Imaging and spectral Doppler techniques
 - v) 2-D Interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Diameter
 - Length
 - vi) Spectral Doppler interpretation
 - Normal characteristics
 - Abnormal characteristics
 - Measurements
 - Peak-systolic velocity
 - End-diastolic velocity
 - Velocity ratio
 - Pitfalls of measurements
 - vii) Color Doppler interpretation

Vascular Technology

- Presence/absence of flow
- Direction of flow
- Flow characteristics

viii) Capabilities

ix) Limitations

H. Lymphedema

1. Definition
2. Classification
 - a. Congenital/primary
 - b. Acquired/secondary
3. Treatment

I. Sonographic-Guided Procedures

1. Venous ablation
2. Dialysis access intervention
3. Pseudo aneurysm treatment
4. Endovascular arterial interventions
5. Intravascular ultrasound (IVUS)

Section IX: Quality Measurements

1. Explain importance of test validation
 2. Define sensitivity, specificity, positive and negative predictive values, accuracy and disease prevalence
 3. State the statistical equations to calculate sensitivity, specificity, positive and negative predictive values, accuracy and disease prevalence
 4. Describe the methods used to measure diameter and area reduction
 5. Relate the difference between the angiographic measurements used in the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the European Carotid Surgery Trial (ECST)
-

IX. QUALITY MEASUREMENTSs

A. Statistics

1. Chi-square
2. Sensitivity
3. Specificity
4. Positive predictive value
5. Negative predictive value
6. Overall accuracy
7. Prevalence

B. Measurement of Stenosis

1. Diameter versus area reduction
 - a. Diameter reduction
 - b. Area reduction
2. Angiographic determination of severity compared to color Doppler measurement techniques
 - a. NASCET
 - b. ECST

Vascular Technology

Section X: Sonography Safety

1. Evaluate sonographic image and Doppler spectral quality, and recognize the importance of preventive maintenance of the sonographic system
 2. Define and discuss the biological effects associated with the use of medical sonography
 3. Relate the As Low as Reasonably Achievable (ALARA) principle
-

X. SONOGRAPHY SAFETY

- A. Instrument Performance
 1. Evaluation of image quality
 2. Evaluation of Doppler quality
 3. Preventive maintenance
- B. Biological Effects
 1. Minimizing exposure time
 - a. ALARA principle/prudent use statement
 2. Mechanisms of production
 - a. Mechanical index
 - b. Thermal index
 3. Cavitation effects
 4. Scientific data
 5. Preventing electrical hazards

Vascular Technology

Abbreviations

A

AC	Alternating Current
ACA	Anterior Cerebral Artery
ACoA	Anterior Communicating Artery
AV	Arteriovenous

B

Bas	Basilar Artery
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C

CCA	Common Carotid Artery
CEAP	Clinical Etiologic Anatomic Pathologic Classification
CEUS	Contrast Enhanced Ultrasound

CFA	Common Femoral Artery
CFV	Common Femoral Vein
CRT	Cathode Ray Tube
CTA	Computed Tomographic Angiography
CTV	Computed Tomographic Venography
CVA	Cerebrovascular Accident
CVI	Chronic Venous Insufficiency
CW	Continuous Wave Doppler

D

DC	Direct Current
DICOM	Digital Imaging and Communications in Medicine
DSA	Digital Subtraction Angiography

E

ECA	External Carotid Artery
ECST	European Carotid Surgery Trial
EDV	End-Diastolic Velocity

F

FMD	Fibromuscular Dysplasia
FV	Femoral Vein

I

ICA	Internal Carotid Artery
IMA	Inferior Mesenteric Artery; Internal Mammary Artery
IMT	Intimal Medial Thickness
IMV	Inferior Mesenteric Vein
IVC	Inferior Vena Cava

M

MCA	Middle Cerebral Artery
MRA	Magnetic Resonance Arteriography
MRV	Magnetic Resonance Venography

N

NASCET	North American Symptomatic Carotid Endarterectomy Trial
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O

OPG-Gee	Oculopneumoplethysmography-Gee
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Vascular Technology

P

PACS	Picture Archiving Communication System
PCA	Posterior Cerebral Artery
PCoA	Posterior Communicating Artery
PCS	Pelvic Congestion Syndrome
PE	Pulmonary Embolism
PI	Pulsatility Index
PPG	Photoplethysmography
PSV	Peak-Systolic Velocity
PTA	Percutaneous Transluminal Angioplasty
PW	Pulsed Wave Doppler

R

RI	Resistive Index
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S

SFA	Superficial Femoral Artery
SMA	Superior Mesenteric Artery

T

TCD	Transcranial Doppler
TCI	Transcranial Imaging
TCPO2	Transcutaneous Oxygen
TGC	Time Gain Compensation
TIA	Transient Ischemic Attack
TOS	Thoracic Outlet Syndrome

V

VBI	Vertebrobasilar Insufficiency
VRT	Venous Refill Time

Vascular Technology

Utilized References

1. AbuRahma AF, Bergan JJ. Noninvasive Vascular Diagnosis, 4th ed. Springer-Verlag, London, 2017.
2. Alexandrov AV. Cerebrovascular Ultrasound in Stroke Prevention and Treatment. 2nd ed. Wiley-Blackwell West Sussex, UK, 2011.
3. Curry RA, Tempkin BB. Sonography: Introduction to Normal Structure and Function. 3rd ed. Elsevier Saunders, St. Louis, 2010.
4. Daigle RJ. Techniques in Noninvasive Vascular Diagnosis. 5th ed. Summer Publishing, Littleton, 2023.
5. Edelman SK. Understanding Ultrasound Physics, 4th ed. ESP, 2012.
6. Gorman, et al., editors. The Sonographer Training HUB. The International Contrast Ultrasound Society, 2022, [www. https://icus-society.org/education/sonographer-training-resource-hub/](https://icus-society.org/education/sonographer-training-resource-hub/)
7. Hedrick WR, Hykes DL, Starchman DE. Ultrasound Physics and Instrumentation, 4th ed., Mosby-Year Book, Inc., St. Louis, 2004.
8. Kremkau FW. Diagnostic Ultrasound, Principles and Instrumentation, 8th ed. WB Saunders, Inc., 2010.
9. Lyshchik, A. Fundamentals of CEUS. Elsevier, Philadelphia, PA, 2019.
10. Miele FR. Ultrasound Physics & Instrumentation, 6th ed. Miele Enterprises, Forney, 2022.
11. Pellerito JS and Polak, J., Introduction to Vascular Ultrasonography, 6th ed. St. Louis, MO: Elsevier (Saunders), 2012.
12. Ridgway DP. Introduction to Vascular Scanning: A Guide for the Complete Beginner, 4th ed. Davies Publishing, Inc., Pasadena, 2014.
13. Scissons R. Physiologic Testing Techniques and Interpretation. Unetixs Educational Publishing, Rhode Island, 2003.
14. Tegeler CH, Babikian VL, Gomez CR. Neurosonology. Mosby-Year Book, Inc., St. Louis, 1996.
15. Uflacker R. Atlas of Vascular Anatomy, 3rd ed. Williams & Wilkins, Baltimore, 2020.