

# **CLINICAL CURRICULUM AND EDUCATIONAL OBJECTIVES FOR VASCULAR SURGERY**

Developed by the Association of Program Directors in Vascular Surgery

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## General:

Each of the categories in the Clinical Curriculum is assumed to include the diagnosis and management of the problem for all etiologies to include atherosclerosis, trauma, infection, etc. where appropriate. A general understanding of each topic in the Clinical Curriculum is expected at the completion of vascular surgery training. In addition, the trainee is expected to know the natural history of the various diseases. Knowledge of additional/non-core topics will be encouraged but not required.

Educational objectives have also been developed for each section of the Clinical Curriculum. It is expected that these objectives will be achieved by each trainee at the completion of training. Included are selected references for each set of objectives that are suggested as minimal background reading for each section.

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## **CLINICAL CURRICULUM FOR VASCULAR SURGERY**

### **1. Diagnosis and Management of Aneurysmal Disease**

Includes:

- Aortic and Iliac Artery Aneurysms
- Peripheral Artery Aneurysms
- Extra-cranial Carotid Aneurysms
- Subclavian/Axillary Artery Aneurysms
- Femoral/Popliteal Artery Aneurysms
- Splanchnic and Renal Artery Aneurysms
- Thoracoabdominal Aortic Aneurysms
- Thoracic Aortic Aneurysms
- Thoracic/Abdominal Aortic Dissection

### **2. Diagnosis and Management of Extremity Arterial Occlusive Disease**

Includes:

- Aortoiliac Occlusive Disease
- Femoral-Popliteal-Tibial Occlusive Disease
- Upper Extremity Occlusive Disease
- Combined Aortoiliac and Infrainguinal Occlusive Disease
- Arterial Bypass Graft Surveillance
- Failing Arterial Bypass Graft
- Ischemic Foot Lesions

### **3. Diagnosis and Management of Renal Artery Occlusive Disease**

Includes:

- Renovascular Hypertension
- Ischemic Nephropathy
- Renal Artery Surgery
- Renal Angioplasty
- Diagnostic Studies to Detect Functionally Significant
- Renal Artery Stenosis

Additional Important/None-Core Curriculum Topics:

- Renal Arteriovenous Fistulae

### **4. Diagnosis and Management of Visceral Ischemia**

Includes:

- Chronic Visceral Ischemia

Acute Visceral Ischemia  
Non-Occlusive Mesenteric Ischemia  
Mesenteric Venous Occlusive Disease

Additional Important/Non-Core Curriculum Topics:

Celiac/SMA Compression

**5. Diagnosis and Management of Carotid Artery Occlusive Disease**

Includes:

Atherosclerotic Carotid Artery Disease  
Carotid Artery Fibromuscular Dysplasia  
Carotid Artery Coils and Kinks  
Carotid Artery Radiation Injury  
Carotid Body Tumor  
Overall Management of Stroke  
Spontaneous Carotid Artery Dissection  
Atherosclerotic Aortic Arch Disease Leading to Proximal  
Carotid Artery Stenosis

**6. Diagnosis and Management of Innominate, Subclavian and Vertebrobasilar Arterial Disease**

Includes:

Stenotic and Embolic Innominate Artery Disease  
Stenotic and Embolic Vertebral Artery Disease  
Stenotic and Embolic Subclavian Artery Disease  
Subclavian Steal Syndrome

Additional Important/Non-Core Curriculum Topics:

Vertebral Arteriovenous Fistulae

**7. Diagnosis and Management of Thoracic Outlet Syndrome**

Includes:

Cervical Rib/Abnormal First Rib  
Arterial Complications  
Venous Complications  
Neurogenic Complications

**8. Diagnosis and Management of Acute Arterial Occlusion**

Includes:

Acute Thrombotic Disease

Atheroembolic Disease  
Thromboembolectomy Techniques  
Thrombolysis: Percutaneous & Intraoperative  
Systemic Complications of Reperfusion Injury  
Compartment Syndrome

**9. Diagnosis and Management of Diabetic Foot Problems**

Includes:

Pathophysiology of Ischemia, Neuropathy and Infection  
Antibiotic Treatment  
Amputation Types  
Wound Management  
Foot Care

Additional Important/Non-Core Curriculum Topics:

Orthotic Management

**10. Diagnosis and Management of Complications of Vascular Therapy**

Includes:

Pseudoaneurysms  
Aortoenteric Fistulae/Erosions  
Vascular Graft Infections  
Colon Ischemia after Aortic Surgery  
Chronic Perigraft Seromas  
Occluded Prosthetic Grafts  
Prosthetic Graft Dilatation

**11. Diagnosis and Management of Vascular Trauma**

Includes:

Aortic Trauma  
Carotid Trauma  
Brachiocephalic Trauma  
Visceral Arterial Trauma  
Extremity Trauma  
Venous Trauma  
Diagnosis of Vascular Trauma - Arteriography/Duplex  
Nonoperative Therapy  
Traumatic A-V Fistulas  
Iatrogenic Vascular Trauma

Additional Important/Non-Core Curriculum Topics:

Associated Neural Injury

**12. Diagnosis and Management of Venous Thromboembolic Disease**

Includes:

- Deep Venous Thrombosis
- Deep Venous Thrombosis Prophylaxis
- Pulmonary Emboli
- Caval Interruption
- Subclavian/Axillary Thrombosis
- Venous Thrombectomy/Thrombolytic Therapy
- Anticoagulation

Additional Important/Non-Core Curriculum Topics:

- Acute Caval Thrombosis Syndrome
- Pulmonary Embolectomy (open & catheter based)
- Renal Vein Thrombosis
- Budd-Chiari Syndrome

**13. Diagnosis and Management of Chronic Venous Insufficiency**

Includes:

- Noninvasive Diagnosis
- Medical Treatment
- Sclerotherapy
- Surgical Reconstruction including Subfascial Ligation of Perforators, Valvular
- Congenital Causes

**14. Diagnosis and Management of Lymphedema**

**15. Indications and Techniques for Extremity Amputation**

Includes:

- Determination of Amputation Level

Additional Important/Non-Core Curriculum Topics:

- Post-Amputation Care
- Prosthetic Management
- Rehabilitation
- Phantom Pain Symptoms

**16. Techniques for the Diagnosis of Peripheral Vascular Disease**

Includes:

- Hemodynamic Assessment of Arterial and Venous Disease

Duplex Evaluation of Carotid, Venous, Mesenteric, Renal  
and Extremity Vascular Disease  
Arteriography  
Computerized Tomography  
MRI/MRA  
Intraoperative Duplex Evaluation

Additional Important/Non-Core Curriculum Topics:

Intravascular Ultrasound

**17. Use of Endovascular Therapy in the Management of Peripheral Vascular Disease**

Includes:

Lytic Therapy  
Balloon Angioplasty  
Endoluminal Stents  
Stent Grafts  
Angioscopy  
Endoluminal Ultrasound  
Embolization

**18. Risk Stratification in Patients with Peripheral Vascular Disease**

Includes:

Cardiac Risk Evaluation  
Pulmonary Risk Evaluation  
Atherosclerotic Risk Factor Assessment  
Lipid Disorder Evaluation and Management

**19. Diagnosis and Management of Coagulation Disorders in Patients with Peripheral Vascular Disease**

Includes:

Bleeding Disorders/Intraoperative Bleeding  
Heparin Associated Thrombocytopenia  
Hypercoagulable States  
Low Molecular Weight Heparin  
Antiplatelet Agents Including Ticlopidine

**20. Diagnosis and Management of Miscellaneous Vasculogenic Problems**

Includes:

Vasospastic Diseases  
Neurogenic Thoracic Outlet Syndrome  
Causalgia/Reflex Sympathetic Dystrophy

Additional Important/Non-Core Curriculum Topics:

Vasculogenic Impotence  
Pediatric Vascular Disorders  
Frostbite

**21. Diagnosis and Management of Non-Atherosclerotic Vascular Diseases**

Includes:

Systemic Vasculitis  
    Giant Cell Arteritis  
    Takayasu's Disease  
Radiation Induced Arterial Disease  
Arterial Infections  
Adventitial Cystic Disease  
Popliteal Entrapment Syndrome  
Buerger's Disease  
Congenital Problems  
    Coarctation  
    Persistent Sciatic Artery  
    Aberrant Subclavian Artery  
Arteriopathies  
    Marfan's Syndrome  
    Ehlers-Danlos Syndrome  
    Arterial Magna Syndrome  
    Cystic Medical Necrosis  
    Behcet's Disease  
Homocystinuria  
Intra-Arterial Drug Induced Injury

**22. Diagnosis and Management of Arterial Venous Malformations**

Includes:

Surgical, Catheter and Nonoperative Management  
of Angiodysplasias

**23. Indications for and Techniques of Vascular Access**

Includes:

Vascular Access for Hemodialysis  
Ischemic Hand After Vascular Access  
Peripheral Dialysis Access

**24. Indications for and Results of Sympathectomy in Patients with Peripheral Vascular Disease**

**25. Diagnosis and Management of Portal Hypertension**

## EDUCATIONAL OBJECTIVES

### 1. **Aneurysmal Disease**

William H. Pearce, M.D., Christopher Zarins, M.D., John W. Hallett, M.D.

#### I. Basic Science

1. To describe aortic architecture and functions.
2. To describe hemodynamic changes at major bifurcation and Laplace's Law.
3. To describe the role of aging and atherosclerosis in aortic enlargement.
4. To describe the role of inflammation and proteases in aneurysm formation.
5. To describe the differences in Marfan's disease and Ehlers Danlos syndrome.

#### II. Diagnostic Evaluation

1. To understand the incidence and prevalence of aneurysmal disease according to age.
2. To understand the natural history of abdominal aortic aneurysms.
3. To understand the genetic distribution of the disease.
4. To understand the roles of ultrasound, angiography, CT and MRI/MRA in screening and in planning surgery.

#### III. Treatment

1. To understand the indications for surgical repair and the factors which contribute to surgical decision making.
2. To understand the technical aspects of aortic aneurysm repair and surgical options and alternatives.
3. To describe the surgical management of complex aortic aneurysms (including horseshoe kidneys, aortocaval and aorto duodenal fistulae, mycotic, inflammatory).
4. To have knowledge of both the immediate and long-term outcomes of surgery for aortic aneurysmal disease (including symptomatic, asymptomatic, thoracoabdominal, juxtarenal, infrarenal and recurrent).
5. To describe the management and prevention of surgical complications including spinal cord ischemia, distal embolization, myocardial infarction, graft infection.

#### References

1. Dietz HC, Pyeritz RE, Puffenberger EG, et al. Marfan phenotype variability in a family segregating a missense mutation in the epidermal growth factor-like motif of the fibrillin gene. *J Clin Invest.* 1992;89:1674-1680.
2. Dobrin PD, Baker WH, Gley WC. Elastolytic and collagenolytic studies of arteries: Implications for the mechanical properties of aneurysms. *Arch Surg.* 1984;119:405-409.
3. Dobrin PD. Mechanical properties of arteries. *Physiol Rev.* 1978;58:397-460
4. Finkbohner R, Johnston D, Crawford ES, Coselli J, Milewicz DM. Marfan syndrome: Long-term survival and complications after aortic aneurysm repair. *Circulation.* 1995;91:728-733.
5. Glagov S, Weisenberg E, Kolettis G, Stankunavicius R, Zarins CK. Compensatory enlargement of human atherosclerotic coronary arteries. *N Engl J Med.* 1987;316:1371-1375.
6. Kivirikko KI. Collagens and their abnormalities in a wide spectrum of diseases. *Ann Med* 1993;25:113-26.
7. Mattar SG, Kumar AG, Lumsden AB. Vascular complications in Ehlers-Danlos syndrome. *The American Surgeon* 1994;60:827-31.

8. Pearce WH, Slaughter MS, LeMaire S, Salyapongse AN, Feinglass J, McCarthy WJ, Yao JST: Aortic diameter as a function of age, gender and body surface area. *Surgery*, 1993;114:691-697.
9. Rizzo RJ, McCarthy WJ, Dixit SN, Lilly MP, Shively VP, Flinn WR. Collagen types and matrix protein content in human abdominal aortic aneurysms. *J Vasc Surg*. 1989;10:365-373.
10. Sumner DS, Hokanson DE, Strandness DE. Stress-strain characteristics and collagen-elastin content of abdominal aortic aneurysms. *Surg Gynecol Obstet*. 1970;130:459-466.
11. Zarins CK, Xu C, Glagov S. Aneurysmal enlargement of the aorta during regression of experimental atherosclerosis. *J Vasc Surg*. 1992;15:90-101.
12. Zatina MA, Zarins CK, Gewertz BL, Glagov S. Role of medial lamellar architecture in the pathogenesis of aortic aneurysms. *J Vasc Surg*. 1984;1(3):442-8.
13. Bergquist D, Bengtsson H, Svensjo S. Prevalence of abdominal aortic aneurysms: Experience from Malmo, Sweden In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment*, Appleton & Lange, Norwalk CT, 1994, pp 49-61.
14. Bickerstaff LK, Pairolero PC, Hollier LH, et al. Thoracic aortic aneurysms: a population-based study. *Surgery*. 1982;92:1103-1108.
15. Blebea J, Kempczinski RF. Mycotic aneurysms. In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment*, Appleton & Lange, 1994 pp 389-410.
16. Collin J, Epidemiological aspects of abdominal aortic aneurysm. *Eur J Vasc Surg*. 1990;4:113-116.
17. Ernst CB. Abdominal aortic aneurysm. *N Engl J Med*. 1993;328:1167-1172. Goldstone J. Aneurysm and fistula to vena cava or gastrointestinal tract: Diagnosis and management. In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment*, Appleton & Lange, 1994 pp 287-303.
18. Hallett JW. Abdominal aortic aneurysm: Natural history and treatment. *Heart Dis Stroke*. 1992;1:303-308.
19. Hollier LH, Taylor LM, Ochsner J. Recommended indications for operative treatment of abdominal aortic aneurysms: Report of a subcommittee of the Joint Council of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery. *J Vasc Surg*. 1992;15(6):1046-56.
20. Johnston KW. Canadian study of the late results of abdominal aortic aneurysm repair. In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment*, Appleton & Lange, 1994 pp 79-87.
21. Johnston KW. Multicenter prospective study of nonruptured abdominal aortic aneurysm. Part II. Variables predicting morbidity and mortality. *J Vasc Surg*. 1988;9:437-447.
22. Reddy DJ. Surgical treatment of infected abdominal aortic aneurysm: In: Ernst CB, Stanley JC, eds. *Current Therapy in Vascular Surgery*. 2nd ed. Philadelphia: Decker;1991:272-276.
23. Calcagno D, Hallett JW, Ballard DJ, Naessens JM, Cherry KJ, Glociczki P, Pairolero PC. Late iliac artery aneurysms and occlusive disease after aortic tube grafts for abdominal aortic aneurysm repair. A 35-year experience. *Ann Surg*. 1991;214(6):733-6.
24. Coselli JS, Crawford ES. Thoracoabdominal aortic aneurysms. In: Yao JST, Pearce WH, eds. *Long-Term Results in Vascular Surgery*. Appleton & Lange, Norwalk, CT, 1993 pp 135-147.
25. Coselli JS. Contribution of E. Stanley Crawford in thoracoabdominal aortic aneurysms. In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment*. Appleton & Lange, Norwalk, CT, 1994 pp 173-194.
26. Crawford ES, Beckett WC, Greer MS. Juxtarenal infrarenal abdominal aortic aneurysm. *Ann Surg*. 1986;203:661-670.
27. Crawford ES, DeNatale RW. Thoracoabdominal aortic aneurysm: observations regarding the natural course of the disease. *J Vasc Surg*. 1986;3:578-582.
28. Crawford ES, Svensson LG, Coselli JS, et al. Aortic dissection and dissecting aortic aneurysms. *Ann Surg*. 1988;208:254-273.
29. Hallett JW. The fate of aortic tube grafts for abdominal aortic aneurysm repair. In: Yao JST, Pearce WH, eds. *Long-Term Results in Vascular Surgery*. Appleton & Lange, Norwalk, CT, 1993 pp 163-170.
30. Katz KA, Cronenwett JL. The cost-effectiveness of early surgery versus watchful waiting in the

management of small abdominal aortic aneurysms. *J Vasc Surg.* 1994;19(6):980-90.

31. Kieffer E, le Blevec D, Koskas F, Bahnini A, Godet G, Chiras J. Spinal cord protection in surgical repair of thoracoabdominal aneurysm: preoperative and intraoperative measures. In: Yao JST, Pearce WH, eds. *Aneurysms: New Findings and Treatment.* Appleton & Lange, Norwalk, CT, 1994 pp 195-205.

32. Pennell RC, Hollier LH, Lie JT, Bernatz PE, Joyce JW, Pairolero PC, Cherry KJ, Hallett JW. Inflammatory abdominal aortic aneurysms: a thirty-year review. *J Vasc Surg.* 1985; 2(6):859-69.

33. Svensson LG, Crawford ES, Hess KR, et al. Dissection of the aorta and dissecting aortic aneurysms: improving early and long-term surgical results. *Circulation.* 1990;82:IV-24-38.

## 2. **Peripheral Vascular Occlusive Disease**

Anthony D. Whittmore, M.D., James M. Seeger, M.D., Jon R. Cohen, M.D.

### I. Anatomy & Pathophysiology

1. To define the normal arterial anatomy of the peripheral vascular system including commonly encountered anatomic variations.
2. To recognize the physiologic and pathophysiologic collateral circulatory routes which commonly develop in response to occlusive disease.
3. To understand the neural, humoral and pharmacologic mechanisms which affect peripheral vascular reactivity and auto-regulatory function.
4. To appreciate the multiple etiologies of acute peripheral vascular ischemia including embolism, thrombosis, dissection, venous occlusion, trauma.
5. To appreciate the multiple etiologies of chronic peripheral vascular ischemia including atherosclerosis, aneurysm, entrapment syndromes, trauma, and a variety of non-atherosclerotic occlusive entities.
6. To understand the mechanism of early and late graft failure, fibro-intimal hyperplasia and progression of disease.

### II. Diagnostic Evaluation

#### Acute Peripheral Ischemia

1. To understand the signs and symptoms characteristic of acute arterial ischemia and the differential diagnosis.
2. To understand the importance of assessing the degree of acute ischemia.
3. To appreciate the significance of the duration of acute ischemia.
4. To recognize the importance of antecedent clinical entities which may predispose to acute peripheral ischemia including atrial fibrillation, prior myocardial infarction, aortic dissection and hypercoagulopathies.
5. To appreciate the significance of initial electrolyte, acid base and other laboratory parameters useful in assessing the magnitude of ischemia to define the indications for appropriate therapy.
6. To understand the relative indications for immediate diagnostic angiography versus urgent surgical exploration.
7. To understand the arteriographic findings characteristic of different etiologies and to appreciate the diagnostic imaging options available in addition to arteriography (MRA, CT, duplex imaging).

#### Chronic Peripheral Vascular Ischemia

1. To understand the characteristic signs and symptoms of chronic peripheral vascular ischemia relative to the patient's history and physical examination.
2. To understand the importance of appropriate imaging studies prior to formulating a therapeutic management plan.
3. To understand the importance of hemodynamic testing in the formulation of a therapeutic management plan.
4. To appreciate the characteristic angiographic findings in patients with common patterns of peripheral vascular occlusion as well as the importance of assessing available collaterals.

### III. Treatment

#### Acute Peripheral Vascular Ischemia

1. To appreciate the relative indications for immediate angiography, thrombolytic therapy, or urgent surgical exploration relative to the duration of symptoms and magnitude of ischemia.
2. To have a comprehensive understanding of the variety of surgical exposures of the peripheral vasculature.
3. To understand the relative indications for the major surgical options available for peripheral occlusive disease including endarterectomy, patch angioplasty and bypass graft (autogenous versus prosthetic).
4. To understand the role of intra-operative thrombolytic agents, dosage and mechanisms of action.

5. To appreciate the sequela of reperfusion following acute ischemia in terms of systemic effects as well as local effects warranting fasciotomy including the anatomy and physiology of fasciotomy.
6. To be familiar with endovascular options for the treatment of occlusive disease including atherectomy, laser, balloon angioplasty, stent graft, as well as the role of angioscopy.
7. To understand the importance of completion imaging studies following peripheral arterial reconstruction.

#### Chronic Peripheral Vascular Ischemia

1. To have a comprehensive understanding of all standard surgical approaches for surgical revascularization including endarterectomy, patch angioplasty and bypass (in -situ and reversed vein grafts, prosthetic grafts).
2. To understand the difference in application of options relative to the degree of ischemia (claudication versus critical ischemia, with or without tissue necrosis).
3. To understand indications for primary amputation.
4. To have an understanding of the role of endovascular approaches including laser, atherectomy, thrombectomy, balloon dilatation with or without stent, and angioscopy.
5. To have a comprehensive knowledge of popliteal entrapment and adventitial cystic disease and their treatment.
6. To understand the necessity for post revascularization non-invasive hemodynamic assessment and criteria for reintervention for a failing of failed bypass.

#### References

1. Boyd, AM: The natural course of arteriosclerosis of lower extremities. Proc R Soc Med 55:591, 1962.
2. Patent FN, Piotrowski JJ, Bernhard VM, et al: Outcome of intraarterial urokinase for acute vascular occlusion. J Cardiovasc Surg 32:680, 1991.
3. Thompson RW, Mannick JA, Whiteemore AD: Arterial reconstruction at diverse sites using nonreversed autogenous vein: An application of venous valvulotomy. Ann Surg 205:747, 1987.
4. Veith FJ, Gupta SK, Ascer E, et al: Six -year prospective multicenter randomized comparison of autologous saphenous vein and expanded polytetrafluoroethylene graft in infrainguinal arterial reconstruction. J Vasc Surg 3:104, 1986.
5. Taylor RS, McFarland RF, Cox MI: An investigation into the causes of failure of PTFE grafts. Eur J Vasc Surg 1:335, 1987.
6. Gilbertson JJ, Walsh DB, Zwolak RM, et al: A blinded comparison of angiography, angioscopy, and duplex scanning in the intraoperative evaluation of in situ saphenous vein bypass grafts. J Vasc Surg 15:121, 1992.
7. Whittemore AD, Clowes AW, Couch NP, Mannick JA: Secondary reconstruction. Ann Surg 193:35, 1981.
8. Bandyk DF, Schmitt DD, Seabrook GR, et al: Monitoring functional patency of in situ saphenous vein bypasses: The impact of a surveillance protocol and elective revision. J Vasc Surg 9:286, 1989.
9. Bergamini TM, Towne JB, Bandyk DF, et al: Experience with in situ saphenous vein bypasses during 1981 to 1989: Determinant factors of long-term patency. J Vasc Surg 13:137, 1991.
10. Donaldson MC, Mannick JA, Whittemore AD: Causes of primary graft failure after in situ saphenous vein bypass grafting. J Vasc Surg 15:113, 1992.

### 3. **Renal Artery Disease**

Kimberly J. Hansen, M.D., Robert G. Atnip, Jr., M.D., Gregorio A. Sicard, M.D.

#### I. Anatomy and Pathophysiology

1. To define normal renal artery anatomy and collateral pathways important in renal artery disease.
2. To understand the etiology, pathology and natural history of these renal artery lesions:
  - a. Renal artery atherosclerosis
  - b. Renal artery fibromuscular dysplasia
  - c. Renal artery aneurysm
  - d. Renal arteriovenous malformation
  - e. Takayasu's arteritis
  - f. Middle aortic syndrome/congenital hypoplasia
  - g. Atheroembolic disease
  - h. Renal artery trauma
  - i. Embolic occlusion
  - j. Renal artery dissection
3. To define common co-existing extrarenal diseases associated with the various renal artery lesions.
4. To understand the exocrine and endocrine function of the kidney, and relate these to the structure and function of the nephron unit.
5. To understand the renin-angiotensin axis in the absence and presence of renal artery disease.
6. To describe the mechanisms of renovascular hypertension and renovascular insufficiency (i.e., ischemic nephropathy) and to understand how these differ for unilateral and bilateral renal artery disease.

#### II. Diagnostic Evaluation

##### Screening and Imaging

1. To describe the clinical features of renovascular hypertension and renovascular insufficiency, and to contrast these with essential hypertension and parenchymal renal failure.
2. To describe the performance and diagnostic criteria for these screening/imaging studies:
  - a. Captopril renin test
  - b. Captopril renography
  - c. Intravenous urography
  - d. Ultrasonography
    1. Duplex sonography
    2. Intravascular sonography
  - e. Spiral computerized tomography
  - f. Magnetic resonance imaging
  - g. Angiography
    1. Digital subtraction angiography
      - a. Intravenous
      - b. Intra-arterial
    2. Cut-film angiography
    3. CO<sub>2</sub> angiography
3. To define the applications and limitations of available screening/imaging studies.

##### Tests of Functional Significance

1. To distinguish between functionally significant and clinically silent renal artery disease.
2. To define the selection and patient preparation for these studies of functional significance:
  - a. Split renal function test
  - b. Selective renal vein renin determination
  - c. Peripheral plasma renin determination

- d. Captopril renin test
  - e. Captopril renography
3. To describe the diagnostic criteria, predictive value and limitations of each study of physiologic significance.

### III. Treatment

1. To describe the strategies, options and anticipated results of medical management for the various renal artery lesions.
2. To appreciate the limitations and complications associated with medical management of renovascular hypertension and renovascular insufficiency.
3. To understand the indications, anticipated anatomic results and clinical response associated with catheter-based intervention for the various renal artery lesions:
  - a. PTA ± intravascular stenting
  - b. Athrectomy
  - c. Fibrinolytic therapy
4. To understand the indications for surgical renal artery reconstruction as they relate to the various renal artery lesions.
5. To define the techniques of surgical exposure for renal artery lesions.
6. To understand the selection and performance of direct and indirect reconstruction for the different renal artery lesions:
  - a. Direct reconstruction
    1. Aortorenal bypass
    2. Endarterectomy
      - a. Transaortic
      - b. Transrenal
    3. Reimplantation
    4. Ex vivo reconstruction
  - b. Indirect reconstruction
    1. Splanchnorenal bypass
      - a. Splenorenal
      - b. Hepatorenal
      - c. Nephrectomy
7. To describe the anticipated results of reconstruction and nephrectomy as they relate to response, renal function response, subsequent cardiovascular events and patient survival.      hypertension
8. To define the management of silent and functionally significant renal artery lesions      combined with occlusive or aneurysmal aortic disease.
9. To recognize and develop a plan of management for complications associated with surgical management of renal artery disease and understand how these complications relate to co-existing renal and extrarenal disease.

### References

1. Robaczewski, DL, Dean RH. Renovascular hypertension. In: Sidawy AN, Sumpio BE, DePalma RG, eds. The basic science of vascular disease. Armonk, NY:Futura Publishing Company, Inc. (In Press)
2. Martinez-Maldonado M. Pathophysiology of renovascular hypertension. Hypertension 1991;17:708.
3. Gomez RA, Chevalier RL, Carey RL, Peach MJ. Molecular biology of the renal renin-angiotensin system. Kidney Int 1990;38(30):S18.
4. Dean RH, Benjamin ME, Hansen KJ. Surgical management of renovascular hypertension. In: Wells SA, Jr., eds. Current problems in surgery. St. Louis: Mosby-Year Book, Inc. (In Press)
5. Dean RH, Kieffer RW, Smith BM, et al. Renovascular hypertension: anatomic and renal function changes during drug therapy. Arch Surg 1981;116:1408.

6. Dean RH, Tribble RW, Hansen KJ, et al. Evolution of renal insufficiency in ischemic nephropathy. *Ann Surg* 1991;213:446.
7. Libertino JA, Flam TA, Zinman LN, et al. Changing concepts in surgical management of renovascular hypertension. *Arch Intern Med* 1988;148:357.
8. Reilly JM, Rubin BG, Thompson RW, Allen BT, Anderson CB, Sicard GA. Long-term effectiveness of extra-anatomic renal artery revascularization. *Surgery* 1994;116(4):784.
9. Atnip RG, Neumyer MM, Healy DA, et al. Combined aortic and visceral arterial reconstruction: risks and result. *J Vasc Surg* 1990;12:705.

#### 4. **Visceral Ischemia**

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##### I. Anatomy and Pathophysiology

1. To define the normal arterial and venous anatomy of the mesenteric circulation and to be familiar with the more frequently encountered anatomic variations.
2. To recognize the physiologic and pathophysiologic collateral circulation to the gastrointestinal tract that may develop in response to occlusive disease of the main mesenteric vessels.
3. To understand the high flow, low resistance physiology of normal mesenteric blood flow, recognize the neural, humoral (hormonal) and enteric (intraluminal) mechanisms of autoregulation, and understand the high degree of vasoreactivity of this arterial bed.
4. To understand the multiple etiologies of acute mesenteric ischemia including embolism, thrombosis, dissection, venous occlusion, trauma, and gut ischemia following aortic reconstruction
5. To understand the multiple possible etiologies of syndromes of chronic mesenteric ischemia including atherosclerosis, aneurysm, extrinsic compression syndromes, and other nonatherosclerotic arteriopathies.
6. To understand the clinical correlation of multiple visceral vessel involvement with the development of symptoms of chronic intestinal ischemia based upon an understanding of the compensatory collateral perfusion of the gut.

##### II. Diagnostic Evaluation

###### Acute Mesenteric Ischemia

1. To understand the characteristic initial signs and symptoms suggestive of acute mesenteric ischemia and how symptoms and physical findings may differ from other causes of the acute abdomen.
2. To define preexistent clinical conditions that may predispose to, or support the clinical diagnosis of acute mesenteric ischemia, e.g. atrial fibrillation, previous myocardial infarction (mesenteric embolism), severe cardiopulmonary dysfunction (non-occlusive ischemia), history of post-prandial pain and weight loss, known aortic dissection (mesenteric thrombosis), hypercoagulable states (mesenteric venous thrombosis).
3. To understand the parameters of initial serologic testing that characterize or may support the clinical diagnosis of acute mesenteric ischemia.
4. To define the indications for mesenteric arteriography (or other forms of visceral arterial imaging) in patients with suspected acute mesenteric ischemia and understand the technical aspects of the conduct of arteriography necessary to make an accurate diagnosis.
5. To define the characteristic arteriographic findings diagnostic of the major causes of acute mesenteric arterial ischemia; mesenteric thrombosis, mesenteric embolism, and non-occlusive mesenteric ischemia.
6. To define the appropriate diagnostic evaluation for suspected intestinal ischemia following aortic surgery.
7. To understand the usefulness of alternative imaging techniques (CT, MRI) for the diagnosis of acute mesenteric venous thrombosis.

###### Chronic Mesenteric Ischemia

1. To understand the characteristic signs and symptoms of chronic mesenteric ischemia and how other aspects of patients' history (e.g. previous aortic surgery) or physical examination (e.g. aortoiliac occlusive disease) may suggest the presence of associated visceral arterial occlusive disease.
2. To understand the limitations of standard gastrointestinal diagnostic testing modalities (e.g. GI endoscopy, contrast studies, CT, etc.) for diagnosis of chronic mesenteric ischemia.
3. To understand the usefulness of porto-mesenteric duplex ultrasound scanning for elective noninvasive evaluation of the major visceral vessels.
4. To define the indications for arteriography (or alternative vascular imaging studies) in patients with suspected chronic mesenteric ischemia and understand the arteriographic findings that are considered diagnostic of this condition.
5. To recognize the characteristic arteriographic findings in atypical causes of mesenteric arterial compromise

including extrinsic compression and nonatherosclerotic visceral arterial disease.

### III. Treatment

#### Acute Mesenteric Ischemia

1. To be familiar with techniques for surgical exposure of the main mesenteric vessels, to understand standard surgical options for revascularization following acute mesenteric embolism or acute mesenteric arterial thrombosis, and to understand surgical options for the management of intestinal necrosis when this has occurred.
2. To recognize the relationship of different anatomic patterns of gut infarction to the different causes of acute mesenteric ischemia when intestinal infarction is encountered unexpectedly at the time of laparotomy.
3. To understand the critical relationships between the extent of viable bowel (before and/or after successful revascularization) and the extent of resection of nonviable intestine, and the impact of these observations upon both the short and long-term prognosis for the patient.
4. To understand the relative usefulness of intraoperative techniques available for the assessment of intestinal viability at the time of surgical treatment for acute mesenteric ischemia.
5. To understand the pathophysiologic effects of intestinal reperfusion after surgical treatment of acute mesenteric ischemia and the impact of these effects on postoperative patient care.
6. To understand the role of early empiric re-exploration following surgical treatment of acute mesenteric ischemia.
7. To understand standard and alternative treatments for mesenteric venous thrombosis including the role of surgical treatment in the management of this disorder.
8. To understand the management of suspected acute gut ischemia occurring after aortic surgery.
9. To understand the therapeutic role of interventional non-surgical treatments in the management of all forms acute mesenteric ischemia, particularly in non-occlusive mesenteric ischemia.

#### Chronic Mesenteric Ischemia

1. To be familiar with all standard surgical techniques for direct, elective visceral revascularization and understand the importance of comprehensive revascularization in the surgical treatment of chronic intestinal ischemia.
2. To be aware of surgical alternatives for treatment of atypical or non-atherosclerotic visceral arterial occlusive lesions.
3. To understand the possible application of interventional, nonsurgical treatments for chronic visceral arterial occlusive lesions.
4. To understand the usefulness of noninvasive vascular testing for the follow-up of patients having visceral revascularization procedures.

#### References

1. Vascular Disease of the Gastrointestinal Tract -Pathophysiology, Recognition, and Management. Marston A, editor. Baltimore: Williams & Wilkins, 1986.
2. Flinn WR, Vogelzang RL eds., Visceral arterial disorders. In Strandness DE, Van Breda A, editors. Vascular diseases - surgical & interventional therapy. New York: Churchill Livingstone, Inc. 1994:743-850.
3. Granger DN, Richardson PDI, Kvietys PR, et al. Intestinal blood flow. Gastroenterology, 1980; 78:837.
4. Clark ET, Gewertz BL. Intermittent ischemia accentuates intestinal reperfusion injury. J Vasc Surg 1991; 13:601.
5. Moneta GL, Cummings C, Yeager RA, et al. Mesenteric duplex scanning: a blinded prospective study. J Vasc Surg; 1993; 17:79.
6. Nemcek AA, Vogelzang RL. Comprehensive visceral arteriography. In Strandness DE, Van Breda A, editors. Vascular diseases - surgical & interventional therapy. New York: Churchill Livingstone, Inc. 1994:763-774.
7. Kaley RN, Sammartano RJ, Boley SJ. Aggressive approach to acute mesenteric ischemia. Surg Clin

North Am 1992; 72:157.

8. Horgan PG, Gorey TF. Operative assessment of intestinal viability. *Surg Clin North Am* 1992; 72:143.
9. Morse SS, Clark RA. Management of nonocclusive and occlusive mesenteric ischemia. In Kadir S, editor. *Current Practice of Interventional Radiology*. Philadelphia: BC Decker 1991:394.
10. Harward TRS, Green D, Bergan JJ, et al. Mesenteric venous thrombosis. *J Vasc Surg* 1989; 9:328.
11. Stoney RJ, Cunningham CG. Chronic visceral ischemia. In Yao JST, Pearce WH, editors. *Long term results in vascular surgery*. Norwalk, Appleton & Lange. 1993:305.
12. Cunningham CG, Reilly LM, Rapp JH. Chronic visceral ischemia: three decades of progress. *Ann Surg* 1991; 214:276.
13. Hermreck AS, Thomas JH, Iliopoulos JI, Pierce GE. Role of supraceliac aortic bypass in visceral arterial reconstruction. *Am J Surg* 1991; 162:611.
14. McAfee MK, Cherry KJ, Naessens JM, et al. Influence of complete revascularization on chronic mesenteric ischemia. *Am J Surg* 1992; 164:220.
15. Calderon M, Ruel GJ, Gregoric ID, et al. Long-term results of surgical management of chronic intestinal angina. *J Cardiovasc Surg* 1992; 33:723.
16. Okuhn SP, Reilly LM, Bennett JB, et al. Intraoperative assessment of renal and visceral artery reconstruction: the role of duplex scanning and spectral analysis. *J Vasc Surg* 1987; 5:137.
17. McMillan WD, McCarthy WJ, Bresticker MR, et al. Mesenteric artery bypass: objective patency determination. *J Vasc Surg* 1995; 21:729.
18. Colapinto RF, McLoughlin MJ, Weisbrod GL. The routine lateral aortogram and the celiac compression syndrome. *Radiology* 1972; 103:557.
19. Golden DA, Ring EJ, Mclean GK, Friedman DB. Percutaneous transluminal angioplasty in the treatment of abdominal angina. *AJR* 1982; 139:247.

## 5. Carotid Artery Disease

Alan M. Graham, M.D., Wesley S. Moore, M.D., William Baker, M.D.

### I. Anatomy and Pathophysiology

1. To describe the anatomy of the arch, great vessels, and intracranial arteries.
2. To describe the embryology of the above and relate the common anomalies to the embryology.
3. Discuss the collateral arterial communications of the extracranial and intracranial arteries.
4. To discuss the diagnosis of anomalies and collateral circulation utilizing diagnostic modalities including CT scan, MRI, SPECT, and transcranial doppler.
5. To understand the different etiologies of carotid artery disease.
  - a. Atherosclerosis
    - i. Define the systemic risk factors for atherosclerosis.
    - ii. Define the systemic effects of atherosclerosis and how these effects impact the diagnosis and treatment of the patient with carotid stenosis.
  - b. Kinking and tortuosity
  - c. Fibromuscular dysplasia
  - d. Compression
  - e. Traumatic occlusion
  - f. Acute Dissection
  - g. Inflammatory arteriopathies
6. To describe the gross pathologic and histologic characteristics of each etiology above.
7. To discuss how each etiology produces cerebral events in terms of occlusion and/or embolism.
8. To discuss the normal flow patterns at the carotid bifurcation, and how they are affected by the atherosclerotic process.

### II. Diagnostic Evaluation

#### History and Physical Examination

1. To define hemispheric, non-hemispheric, and non-specific symptoms.
2. To differentiate among transient ischemic attack (TIA), reversible ischemic neurologic deficit (RIND), stroke in evolution and completed stroke.
3. To describe the arterial and neurologic examination and their importance in caring for patients with carotid artery disease.
4. To describe the relationship between carotid artery atherosclerosis and the clinical syndrome of vertebrobasilar insufficiency.
5. To describe and defend the appropriate evaluation for patients with each of the above clinical presentations.

#### Carotid Duplex Examination

1. To be able to explain the principles of doppler ultrasound.
2. To describe the normal doppler signals in the internal, external, and common carotid arteries.
3. To discuss the sensitivity and specificity of duplex scanning in detecting carotid artery stenosis.
4. To discuss the risks and benefits of relying on duplex ultrasound and eliminating angiography.
5. To understand the basics of P.V. Lab Accreditation.

#### Angiography and MRA

1. Angiography: to be able to discuss the technique, its limitations and complications.
2. MRA: to be able to discuss the technique, limitations and complications.
3. To discuss and compare the different methods of measuring stenosis.

### Diagnostic Brain Scanning

1. For each of the following modalities, explain the principles, indications, complications, and its influence upon the indications for carotid endarterectomy.
  - a. CT scan
  - b. MRI
  - c. SPECT
  - d. Transcranial doppler

### III. Treatment

#### Treatment of Neurologic Syndromes in Patients with Carotid Stenosis

1. To discuss the non-surgical and surgical treatment of acute ischemic syndromes including stroke.
2. To discuss the role of thrombolytic therapy in the treatment of stroke syndrome.
3. To be able to construct a diagnostic and treatment algorithm for various stroke syndromes.
4. To be able to discuss the potential role of endovascular treatment.

#### Surgical Treatment

1. To discuss the intrathoracic and extrathoracic treatment of atherosclerotic stenosis or occlusion of the great vessels.
2. To describe the standard approach to carotid endarterectomy including intraoperative shunting, patching, anesthetic techniques, tacking sutures and methods of completion evaluation.
3. To describe the surgical treatment of fibromuscular dysplasia, kinking, radiation arteritis, tumors involving the carotid artery, other arteritides, and recurrent carotid stenosis.
4. To recognize the carotid sinus syndrome and discuss its treatment.
5. To discuss EC-IC bypass.
6. To discuss the indication and performance of proximal and distal vertebral artery reconstruction.

#### Complication of Carotid Endarterectomy

1. To describe the etiology and management of:
  - a. Wound hematoma
  - b. Wound infection
  - c. Post-operative hyper and hypotension
  - d. Peripheral nerve palsies
  - e. Transient ischemic attack and stroke
  - f. Asymptomatic thrombosis
  - g. Intracranial hemorrhage
  - h. Post-operative seizure
  - i. Extracarotid (cardiac) events

### References

1. Rutherford R. Atlas of Vascular Surgery-Basic Techniques and Exposures. WB Sanders. 1993.
2. Rutherford R. Vascular Surgery. WB Sanders. Fourth Edition. 1995.
3. Kadir S. Diagnostic Angiography. WB Sanders. Philadelphia. 1986.
4. Moore, Wesley. Vascular Surgery: A Comprehensive Review. WB Sanders. Fourth Edition. 1993.
5. Abrams HL. Vascular and Interventional Radiology. Boston. Little. Braine. 1983.
6. Masaryk TJ, Levin JS, Laus G. Magnetic Resonance Angiography. The Mosby Company. St. Louis. 1988:299-334
7. Lee SH, Rao K, Zimmerman RA. Cranial MRI and CT. Thrid Edition. McGraw -Hill. New York. 1992.

8. Fisher M, Sotak CH, Mimematsu K, et al. New Magnetic Resonance Techniques for Evaluating Cerebrovascular Diseases. *Annals of Neurol.* 32(2):115, 1992.
9. Edelman RR, Mattle HP, Atkinson DJ, et al. MR Angiography. *AJR.* 154:937. 1990.
10. Wolfe PA, Kannel WB, McGee DL. Epidemiology of Strokes in North America. *Stroke.* 1:19, 1986.
11. Zarnis CK, Giddens DP, Bharadvaj BK, et al. Carotid Bifurcation Atherosclerosis: Quantitative Correlation of Plaque Location with Flow Velocity Profiles and Wall Shear Stress. *J Circ Res.* 53:502, 1983.
12. Berman SS, Bernhard VM, Erly WK, et al. Critical Carotid Artery Stenosis: Diagnosis, Timing of Surgery, and Outcome. *J Vasc Surg.* 20:499, 1994.
13. Rosenberg H. *CRC Handbook of Carotid Artery Surgery, Facts and Figures.* Second Edition. CRC Press, 1994.
14. Caplan LR. Vertebrobasilar Disease. *Stroke.* 12:111, 1981.
15. Hafer CD. Subclavian Steal Syndrome. *Ann of Surg.* 111:1074, 1976.
16. Johnston KW, Baker WH, Bormham SJ, et al. Quantitative Analysis of Continuous Wave Doppler Spectral Broadening for the Diagnosis of Carotid Disease, Results of a Multicenter Study. *J Vasc Surg.* 4:493, 1986.
17. Moore DJ, Miles RD, Ohgi S, et al. Reactive Accuracy of the Diagnostic Components of Noninvasive Carotid Arterial Tests: A Comparison of Pulsed Doppler Arteriography and Spectrum Analysis. *J Vasc Surg.* 3:502, 1986.
18. Moneta GL, Edwards JM, Chitwood RW, et al. Correlation of North American Symptomatic Carotid Endarterectomy Trial (NASCET) Angiographic Definition of 70% to 99% Internal Carotid Stenosis with Dopley Scanning. *J Vasc Surg.* 17:152, 1993.
19. Moneta GL, Edwards JM, Papanicolaou G, et al. Screening for Asymptomatic Internal Carotid Stenosis: Dopley Criteria for Discriminating 60% to 99% Stenosis. *J Vasc Surg.* 21:989, 1995.
20. Weibel J, Field WS. Tortuosity, Coiling, and Kinking of the Internal Carotid Artery: Etiology and Radiographic Anatomy. *Neurology.* 15:7, 1965.
21. The Casanova Study Grows: Carotid Surgery vs. Medical Therapy in Asymptomatic Carotid Stenosis. *Stroke.* 22:1229, 1991.
22. Hobson RW II, Weiss DG, Fields WS, et al. Efficacy of Carotid Endarterectomy for Aysymptomatic Carotid Stenosis. *N Engl J Med.* 328:221, 1993.
23. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial Effect of Carotid Endarterectomy in Symptomatic Patients with High-Grade Stenosis. *N Engl J Med.* 325:445, 1991.
24. European Carotid Surgery Trialists: Collaborative Group. European Carotid Surgery Trial: Interim Results for Symptomatic Patients with Severe or with Mild Carotid Stenosis. *Lancet.* 337:1235, 1991.
25. Hobson RW II, Weiss DG, Field WS, et al. Efficacy of Carotid Endarterectomy for Aysymptomatic Carotid Stenosis: The Veterans Affairs Cooperative Study Group. *N Eng J Med.* 328:221, 1993.
26. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy For Asymptomatic Carotid Artery Stenosis. *JAMA.* 273:142, 1995.
27. Smith DC, Smith LL, Hasso AN. Fibromuscular Dysplasia of the Internal Carotid Artery Treated by Creative Transluminal Ballon Angioplasty. *Radiology.* 155:645, 1985.
28. Thal ER: Injury to the Neck. In Moore EE, Mattox KL, Feliciano D (eds): *Trauma*, 2nd Ed. Norwalk, Ct. Appleton & Lange. 1988. 305-317
29. Vittl MJ, Thompson BW, Read RC, et al. Carotid-Subclavian Bypass: A Twenty-Two Year Experience. *J Vasc Surg.* 20:44, 1994.
30. Law M, Colburn MD, Moore WS, et al. Carotid-Subclavian Bypass for Brachiocephalic

31. Occulsive Disease. Choice of Conduit and Long-Term Follow-Up. *Stroke*. 26:1565, 1995.  
Jordan WD, Schroeder PT, Fisher WS, McDowell HA. A Comparison of Angioplasty with Stenting versus Endarterectomy for the Treatment of Carotid Artery Stenosis. *Ann Vasc Surg*. 11:2, 1997.
32. Diethrich EB, Ndiaye M, Reid DB. Stenting in the Carotid Artery: Initial Experience in 110 Patients. *J Endovasc Surg*. 3:42, 1996.
33. Stewart MT, Moritz MW, Smith RB, et al. The Natural History of Carotid Fibromuscular Dysplasia. *J Vasc Surg*. 3:305, 1986.
34. Hacke W, Kaste M, Fieschi C, et al. For the ECASS Study Group. Intravenous Thrombolysis with Recombinant Tissue Plasminogen Activator for Acute Hemispheric Stroke: The European Cooperative Acute Stroke Study (ECASS). *JAMA*. 294:1017, 1995.
35. The Multicenter Acute Stroke Trial- Europe Study Group. Thrombolytic Therapy with Streptokinase In Acute Ischemic Stroke. *N Engl J Med*. 335:145, 1996.
36. Wylie's Atlas of Vascular Surgery. Extracranial Cerebrovascular Disease. J.B. Lippencott Company, 1992.

## 6. **Innominate, Subclavian and Vertebrobasilar Arterial Disease**

Ramon Berguer, M.D., Michael DaValle, M.D., Francis Robicsek, M.D.

### I. Etiology, Pathophysiology and History

1. Pathophysiology of atherosclerosis, trauma, dissection, arteritis and radiation as it applies to the innominate, subclavian and vertebrobasilar arteries.
2. Concomitant diseases and associated risk factors commonly associated with stenosis, occlusion, dissection, ulcerated atheroma, arteriovenous fistula and false aneurysm of these arteries.
3. Define the most appropriate diagnostic steps for the evaluation and for the choice of treatment of these conditions.
4. Abnormal and alternative flow patterns that may develop as a consequence of lesions of the innominate, subclavian and vertebrobasilar arteries.
5. Best diagnostic methods available to assess end-organ effects in the brain and upper extremities of the lesions mentioned above.
6. Natural history of these conditions and how this natural history is affected by treatment methods when the latter are successful and when they fail.

### II. Diagnosis

1. Symptoms and signs of brain ischemia in its various manifestations, localized and global, progressive and sudden.
2. Symptoms of ischemia of the upper extremity.
3. Signs of ischemia of the brain or upper extremities elicited by provocative maneuvers .
4. Understand the differential diagnosis of conditions that may present with similar signs or symptoms.
5. Understand how noninvasive tests may suggest or deny the presence of lesions of the innominate, subclavian and vertebrobasilar arteries and how these tests may preclude or indicate arteriography.
6. Understand the anatomy of these arteries and their lesions as defined by arteriography, the timing of films and the best projections to display them.
7. Know the risks involved in arteriography relative to the contrast agents used and their amount, the approach used and the pharmacologic and technical maneuvers employed.
8. Value and shortcomings of CT and MRA/MRI imaging techniques in the diagnosis of these entities.

### III. Treatment

1. Options for (a) medical treatment (antiplatelet, anticoagulant, steroids, antiinflammatory drugs), (b) surgical repair whether direct (endarterectomy, transposition, ligation) indirect (bypass, decompression) or (c) endovascular (angioplasty, stenting, covered stents).
2. Indications for combined treatment and their timing.
3. Possible complications of each of the above treatments and their management.
4. Long-term results with the different treatment options.

### References

1. Kieffer E, Sabatier J, Koskas F, Bahnini A. Atherosclerotic innominate artery occlusive disease: early and long-term results of surgical reconstruction. *J Vasc Surg* 21(2):326-37, 1995.
2. Owens LV, Tinsley EA Jr, Criado E, Burnham SJ, Keagy BA. Extrathoracic reconstruction of arterial occlusive disease involving the supraaortic trunks. *J Vasc Surg* 22(3):217-22, 1995.
3. Berguer R, Kieffer E: *SURGERY OF THE ARTERIES TO THE HEAD*, Springer-Verlag New York Inc., New York, 1992.

## 7. **Thoracic Outlet Syndrome**

Jonathan B. Towne, M.D., John Corson, M.D., Irving Kron, M.D.

### I. Anatomy and Pathophysiology

1. To understand the anatomy of the thoracic outlet to include anatomic variations in bones, muscles, and cervical ribs.
2. To recognize the origin of insertion of the musculoskeletal structures which surround the nerves and blood vessels that supply the arm.
3. To recognize the location of the costovertebral ligaments and the boundaries of the scalene triangle and the costoclavicular space.
4. To recognize the location and incidence of anatomic variations of the insertion of the cervical rib.
5. To recognize insertions of the anterior scalene and its relationship to the neurovascular structures.
6. To recognize the origin and insertion of the subclavius muscle and the possibility of encroaching the neurovascular structures in the costoclavicular triangle.
7. To recognize and define skeletal abnormalities, e.g. elongated C-7 transverse process, callous formation from a fractured clavicle or first rib, hypoplastic first rib, the anatomy of cervical nerves C-5, C-6, C-7, C-8, and T-1, and their relationships to the thoracic outlet.

### II. Diagnostic Evaluation

1. To understand that pain is a principal symptom of neurologic type of thoracic outlet and that the distribution of pain which arises from the upper three nerves of the brachial plexus, C-5, C-6, and C-7, as distinct from the pattern of pain emanating from the lower nerves of the plexus, C-8 and T-1.
2. To recognize the arterial symptoms (embolization to hand and forearm, post stenotic dilatation, and subclavian artery occlusion) and venous symptoms (subclavian vein thrombosis for clinical diagnosis).
3. To understand this may present as spontaneous, related to injury (hyperextension, flexion injuries of the neck, blunt trauma), or that symptoms may occur with hyperadduction of the shoulder or arm exertion.
4. To define differential diagnoses of thoracic outlet to include cervical disc syndrome, carpal tunnel syndrome, orthopedic shoulder problems (shoulder sprain, rotator cuff injuries, tendonitis, cervical spondylitis, ulnar nerve compression at the elbow), Multiple Sclerosis, spinal cord tumor disease, angina pectoris, and Pancoast's tumor.
5. To understand the importance of obtaining blood pressure in both arms, clinical examinations of the hand, examination for muscle atrophy, and evaluation for muscle strain and percussion of the supra clavicular fossa.
6. To understand and have knowledge of tests used to evaluate thoracic outlet, i.e. Adson's test, hyperabduction test, and costoclavicular test.
7. To understand the role of vascular lab in the diagnosis using duplex evaluation to detect thrombosis of the subclavian vein and arterial studies of the upper extremity.
8. To define the physical findings of embolization to the digital vessels and occurrence of palpable aneurysm in the supraclavicular fossa.
9. To recognize the angiographic findings related to this syndrome including false aneurysm, post stenotic dilatation, and subclavian artery occlusion.

### III. Treatment

1. To be familiar with surgical techniques and anatomy for first rib resection (transaxillary, supraclavicular, total anterior scalenotomy).
2. To define specific complications related to the surgical approach (traction injuries to the brachial plexus, pneumothorax, injury of the subclavian artery, injury to the subclavian vein, air embolus as a result of subclavian vein injury, nervous system injury, i.e. long thoracic nerve, intercostobrachial nerve, musculocutaneous nerve).
3. To be aware of the symptoms and incidence of these complications and nerve injuries.

4. To be familiar with the management of subclavian artery aneurysms including the use of graft materials and treatment of distal emboli.
5. To be familiar with thrombolytic therapy in the management of subclavian vein thrombosis.
6. To define the timing of a 1st rib resection with regard to subclavian vein thrombosis.
7. To be aware of the incidence of recurrence of thoracic outlet syndrome.
8. To be aware of the incidence of litigation pertaining to the diagnosis and treatment of thoracic outlet syndrome.
9. To have an understanding of the treatment options to include conservative approaches such as physical therapy and treatment of muscle spasm.

#### References

1. Cheng SWK, Reilly LM, Nelken NA, Ellis WV, Stoney RJ. Neurogenic thoracic outlet decompression: rationale for sparing the first rib. *Cardiovasc Surg* 1995;3:617-623
2. Thompson JF, Jannsen F. Thoracic outlet syndromes (Editorial) *Br J Surg* 1996;83:435-436
3. Mingoli A, Feldhaus RJ, Farina C, Cavallari N, Sapienza P, di Marzo L, Cavallaro A. Long-term outcome after transaxillary approach for thoracic outlet syndrome. *Surgery* 1995;118:840-844
4. Sanders RJ, Cooper MA. Surgical management of subclavian vein obstruction, including six cases of subclavian vein bypass. *Surgery* 1995;118:856-863
5. Juvoen T, Satta J, Laitala P, Luukkonen K, Nissinen. Anomalies at the thoracic outlet are frequent in the general population. *Am J Surg* 1995;170:33-37
6. Lindgren KA, Oksala I. Long-term outcome of surgery for thoracic outlet syndrome. *Am J Surg* 1995;169:358-360
7. Moore WAS, Machleder HI, Poeter JM, Roos DB. Thoracic outlet syndrome (Symposium). *Contemp Surg* 1994;45:99-111
8. Cina C., Whiteacre L, Edwards R, Maggisano R. Treatment of thoracic outlet syndrome with combined scalenectomy and transaxillary first rib resection. *Cardiovasc Surg* 1994;2:514-518
9. Baker MD, Lamerton AJ. Outcome of surgical management of the thoracic outlet compression syndrome in a district general hospital. *Ann Royal Coll Surg Eng* 1993;75:172-174
10. Green RM, McNamara J, Oriel K. Long-term follow-up after thoracic outlet decompression: An analysis of factors determining outcome. *J Vasc Surg* 1991;14:739-46
11. Sanders RJ, Haug C. Review of arterial thoracic outlet syndrome with a report of five new instances. *Surg Gynecol Obstet* 1991;173:415-425
12. Lord Jr, JW. Critical reappraisal of diagnostic and therapeutic modalities for thoracic outlet syndromes. *Surg Gynecol Obstet* 1989;168:337-340
13. Sanders RJ, Jackson CGR, Bancher N, Pearce WH. Scalene muscle abnormalities in traumatic thoracic outlet syndrome. *Am J Surg* 1990;159:231-236
14. Machleder HI. Thoracic outlet syndromes: New concepts from a century of discovery. *Cardiovasc Surg* 1994;2(2):137-145
15. Durham JR, Yao JS, Pearce WH, Nuber GM, McCarthy WJ III. Arterial injuries in the thoracic outlet syndrome (see comments). *J Vasc Surg* 1995;21(1):57-69;discussion 70 Comment in: *J Vasc Surg* 1995;22(1):124-125
16. Jamieson WG, Chinnick B. Thoracic outlet syndrome: Fact or fancy? A review of 409 consecutive patients who underwent operation. *Can J Surg* 1996;39(4):321-326
17. Roos DB. Historical perspectives and anatomic considerations. Thoracic outlet syndrome (Review article). *Sem Thoracic Cardiovasc Surg* 1996;8(2):183-189

## 8. Acute Arterial Occlusion

Keith Calligaro, M.D., David Drezner, M.D., Frank Veith, M.D.

### I. Anatomy and Pathophysiology

1. To understand the various causes of acute arterial thrombosis including chronic atherosclerosis, hypercoagulable conditions, catheters and medical devices, and drug injections.
2. To understand various sources of peripheral arterial emboli including the heart (and underlying factors including myocardial infarcts, valve disease, atrial fibrillation, intracardiac tumors), arterial aneurysms and ulcerative plaques.
3. To define the variable interval of acute arterial ischemia before irreversible changes of the muscle and peripheral nerves begin to occur.
4. To understand the reasons for the high morbidity and mortality associated with acute arterial occlusion even when treatable by simple, straightforward operations.
5. To understand impaired reflow phenomenon including cellular edema, vascular lumen narrowing, capillary occlusion, and oxygen derived radicals.
6. To understand ischemia-reperfusion syndrome and its' complications, including compartment syndrome, hyperkalemia, metabolic acidosis, myoglobinuria and renal insufficiency, and pulmonary insufficiency.
7. To understand the etiology and clinical presentation of "blue-toe syndrome".
8. To understand how the degree of arterial collateralization, in particular chronicity of underlying arterial disease and site of arterial occlusion in reference to major collaterals, affects severity and course of symptoms.

### II. Diagnostic Evaluation

1. To understand the classic signs and symptoms of acute arterial insufficiency (pallor, decreased temperature, pulselessness, paraesthesias, paresis, pain) along with other more subtle findings such as poor venous filling.
2. To be able to recognize features of the viable, threatened and irreversibly ischemic extremity.
3. To correlate other systemic clinical findings with the likely cause of acute arterial occlusion including atrial fibrillation, claudication or a past history of unexplained previous arterial or venous clotting.
4. To understand the utility of doppler studies of peripheral arteries.
5. To understand the indications for preoperative arteriography in the setting of acute arterial occlusion.
6. To understand arteriographic findings suggestive of embolus or thrombus due to underlying arterial stenosis.

### III. Treatment

1. To understand the role of heparin to prevent propagation of thrombus and protect the distal arterial tree.
2. To understand the benefits of mannitol for patients with advanced acute arterial occlusion.
3. To understand the importance of hydration and correcting electrolyte imbalances.
4. To understand the role of thrombolysis as the initial treatment of acute arterial occlusion and its role intraoperatively.
5. To understand the value of full preoperative arteriography in localizing the level of occlusion, the presence of other occlusions and stenoses, and suitable vessels for a bypass should it be needed.
6. To understand the importance of appropriate prepping and draping of the patient to gain access for possible venous conduits and appropriate inflow and outflow arteries.
7. To make correct decisions concerning the proper locations and type of arteriotomy depending on whether an embolus is the likely source of acute arterial occlusion or thrombus secondary to underlying chronic arterial stenosis.
8. To understand the proper technique when using thromboembolectomy catheters.
9. To understand the importance of completion arteriography.
10. To understand the indications for and technique of fasciotomy.

## References

1. Jameson RL. The role of cellular swelling in the pathogenesis of organ ischemia. *West J Med* 1974;3:205.
2. Harman JW. The significance of local vascular phenomena in the production of ischemic necrosis in skeletal muscle. *Am J Pathol* 1948;24:625.
3. McCord JM. Oxygen-derived free radicals in post-ischemic tissue injury. *N Engl J Med* 1985;313:159.
4. Walker PM, Lindsay TF, Labbe R, et al. Salvage of skeletal muscle with free radical scavengers. *J Vasc Surg* 1987;5:68.
5. Perry MO, Shires GT III, Albert SA. Cellular changes with graded limb ischemia and reperfusion. *J Vasc Surg* 1984;1:536.
6. Elliott JP JR, Hageman JH, Szilagyi DE, et al. Arterial embolization: Problems of source, multiplicity, recurrence, and delayed treatment. *Surgery* 1980;88:833.
7. Fogarty TJ, Cranley JJ, Krause RJ, et al. A method for extraction of arterial emboli and thrombi. *Surg Genecol Obstet* 1963;116:241.
8. Abbott WM, Maloney RD, McCabe CC, et al. Arterial embolism. A 44 year perspective. *Am J Surg* 1982;143:460.
9. Thompson JE, Weston AS, Sigler L, et al. Arterial embolectomy after acute myocardial infarction. A study of 31 patients. *Ann Surg* 1970;171:979.
10. Haimovici, H, Moss CM, Veith FJ. Arterial embolectomy revisited. *Surgery* 1975;78:409.
11. Kempczinski RF. Lower extremity arterial embol from ulcerating atherosclerotic plaques. *JAMA* 1979;241:807.
12. Blaisdell FW, Steele M, Allen RE. Management of acute lower extremity arterial ischemia due to embolism and thrombosis. *Surgery* 1978;84:822.
13. Haimovici H. Muscular, renal and metabolic complications of acute arterial occlusions. Myonephropathic-metabolic syndrome. *Surgery* 1979;85:461.
14. Perry MO. Compartment syndromes and reperfusion injury. *Surg Clin North Am* 1988;68:853.
15. Gupta SK, Samson RH, Veith FJ. Embolectomy of the distal part of the popliteal artery. *Surg Gynecol Obstet* 1981;153:255.

## 9. **Diabetic Foot Problems**

Frank W. LoGerfo, M.D., Jennifer Doyle, M.A.

### I. Anatomy and Pathophysiology

1. To define the normal arterial and venous anatomy of the circulation of the foot.
2. To demonstrate an understanding of the etiology of three pathogenic mechanisms underlying problems of the diabetic foot:
  - a. ischemia.
  - b. neuropathy
  - c. infection (polymicrobial nature)
3. To outline factors that can affect blood glucose levels in the peri- and postoperative period

### II. Evaluation and Diagnosis

1. To demonstrate an understanding of the presenting signs and symptoms of three pathogenic mechanisms underlying problems of the diabetic foot:
  - a. ischemia: microvascular abnormalities, atherosclerosis, pattern of atherosclerosis, tibial vessel disease, mediocalcification.
  - b. neuropathy: motor, foot deformities, charcot foot, sensory neuropathy, neuroinflammatory response, manifestations of autonomic neuropathy
  - c. infection: altered clinical picture, metabolic consequences, polymicrobial nature
2. To understand the limitations of various non-invasive tests in the diagnosis of ischemia, the effect of calcified vessels, the role PVR, toe pressures
3. To understand the role of angiography
  - a. susceptibility to contrast induced ARF
  - b. role and techniques of hydration
  - c. need for visualization of foot arteries
4. To evaluate ulcer for ischemia, infection, neuropathy
  - a. use of sterile probe
  - b. role of foot films and interpretation, appearance of charcot changes
5. To accurately interpret clinical laboratory results, pathology reports, and radiographic studies
6. To synthesize historical findings, physical examination and laboratory data for diagnosis;
7. To identify inflow and outflow vessels on an arteriogram
8. To assesses patient's ability to maintain level of activity (walk, drive motor vehicle, work, exercise, sexual activity)

### III. Treatment

1. To understand priorities of management in diabetic patients with foot problems:
  - a. timing and methods of debridement in drainage for sepsis
  - b. metabolic control
  - c. evaluation of ulcer, depth, sepsis, involvement of bone, tendon
  - d. options for conservative management, role of foot gear, weight bearing
  - e. when to evaluate for ischemia
  - f. options in the management of the non-ischemic, purely neuropathic ulcer
2. To understand the role of distal bypass
  - a. role of dorsalis pedis bypass
  - b. alternative inflow sights
  - c. outcome as a function of inflow and outflow site
3. To understand the principles and techniques of wound care, dressing changes, debridement
4. To understand the timing and methods of soft tissue closure
5. To understand the long term importance of glycemic control, weight

6. To recognize the need for careful follow-up and patient education for diabetic patients with foot problems
7. To specify proper dressings and foot care for prevention of problems in diabetic patients, e.g., the role of orthotics, foot gear, nail care
8. To categorize the prevention and management of operative and postoperative complications, including graft infections, graft thrombosis and extremity ischemia
9. To develop familiarity with all techniques of arterial reconstruction including dorsalis pedis bypass and describe the specific role these operations have in management of the diabetic foot
10. To outline the indications for and illustrate the techniques of distal reconstruction, major and minor amputations
11. To outline indications for, and illustrate techniques of:
  - debridement and drainage;
  - arterial reconstruction;
  - vascular bypass grafting;
  - amputation
12. To maintain appropriate control of diabetes peri-operatively, in:
  - NIDDM patient
  - IDDM patient
13. To present an appropriate management plan for the severely septic foot
14. To describe the general outcomes of the diabetes control and complications trial (DCCT) for the purpose of counseling patients
15. To develop appropriate plans for management
16. To manage postoperative surgery and anesthesia complications
17. To delineate and select appropriate postoperative care of patients with diabetes
18. To communicate to patients instructions and expectations for follow-up, such as:
  - pain level and location
  - possible side-effects of medications
  - level of activity and return to work
  - wound care and potential problems
  - timing of follow-up appointment
19. To arrange for home health and other outpatient services using institutional and community resources
20. To understand the role of the surgeon in taking the lead in management of the diabetic foot problem
21. To understand that care of the diabetic foot must necessarily go beyond the vascular reconstruction
22. To appreciate the importance of the team to provide maximum benefit for the patient
23. To demonstrate an understanding of, and sensitivity to, patient socioeconomic concerns regarding such issues as insurance and the ability to pay for physician services, hospitalization, and prescribed medications loss of work time and wages
24. To demonstrate sensitivity and appropriate flexibility regarding patient fears and concerns, including:
  - a. preoperatively - anxiety about pain
  - b. postoperatively - ability to care for self, drugs, level of function, prognosis

#### References

1. Bergman M, Sicard GA [eds.]. Surgical Management of the Diabetic Patient. New York: Raven Press, 1991.
2. Caputo AN, Cavanaugh PR, Ulbrecht JS, Gibbons GW, Karchmer AW. Assessment and Management of Foot Disease in Patients with Diabetes. NEJM 1994, 331:854-860.
3. Cooppan R. General approach to the treatment of diabetes. In: Joslin's Diabetes Mellitus, 13th edition. Lea & Febiger, 1994; pp. 197-403.
4. The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes mellitus on the development and progression of long term complications in insulin dependent diabetes mellitus. NEJM 1993; 329:977-986.

5. Edmonds ME. The Neuropathic Foot in Diabetes. Part I: Blood Flow. *Diabetic Medicine* 1986; 3:111-115.
6. Gibbons GW. Vascular Surgery of the Lower Extremity. In: Frykberg RG, ed. *The High Risk Foot in Diabetes Mellitus*. New York: Churchill Livingstone, 1991, pp. 273-296.
7. Levy LA. Epidemiology and Prevention of Diabetic Foot Disease. In: Frykberg RG, ed.: *The High Risk Foot in Diabetes Mellitus*. New York: Churchill Livingstone, 1991., pp.. 23-30.
8. LoGerfo, Frank W. The Diabetic Foot. In: Richard H. Dean, James S.T. Yao and David C. Brewster, eds., *Current Diagnosis & Treatment in Vascular Surgery*. Norwalk, Connecticut: Appleton & Lange, 1995. Pp. 297-302.
9. LoGerfo FW, Coffman JD. Vascular and microvascular disease in the diabetic foot: Implications for foot care. *NEJM* 1984; 311:1615-19.
10. Maser RE, Wolfson SK Jr, Ellis D, Stein EA, Drash AL, Becker DJ, Dorman JS, Orchard TJ. Cardiovascular disease and arterial calcification in insulin-dependent diabetes mellitus: Interrelations and risk factor profiles. *Arteriosclerosis and Thrombosis*, 1991; 11:958-65.
11. Rosenblum BI, Pomposelli FB Jr, Giurini JM, Gibbons GW, Freeman DV, Chrzan JS, Campbell DR, Habershaw GM, LoGerfo FW. Maximizing foot salvage by a combined approach to foot ischemia and neuropathic ulceration in patients with diabetes mellitus: A five year experience. *Diabetes Care* 1994;17:983-7.
12. Thorne CJM, Siebert JW, et. al. Reconstructive surgery of the lower extremity. In: McCarthy JG, ed. *Plastic Surgery*. Philadelphia: WB Saunders 1990: vol.6:4081-4088.
13. Tooke JE. Microvascular function in human diabetes, a physiological perspective. *Diabetes* 1995; 44:721-725.

## 10. **Complications of Vascular Therapy**

Dennis F. Bandyk, M.D., Jeffrey L. Ballard, M.D., Calvin B. Ernst, M.D.

### I. Anatomy and Pathophysiology

1. To recognize the factors involved in loss of arterial wall and anastomotic tensile strength resulting in the development of pseudoaneurysms.
2. To define the incidence and mechanisms which led to the development of secondary aortoenteric fistulae and erosions.
3. To understand the multiple etiologic factors associated with increased risk of infection following arterial surgery, including biomaterial implantation, host immune factors, concomitant medical conditions, nature and magnitude of bacterial contamination, and wound healing complications.
4. To understand virulence factors of gram-positive and gram-negative microorganisms involved in vascular graft infections.
5. To understand mechanisms involved in bacterial contact, adherence, and colonization of prosthetic graft material.
6. To understand the etiologies causing absence of graft incorporation and perigraft fluid collections including infection, seroma, hematoma, and lymphocele.
7. To define the normal arterial circulation of the colon and anatomic variations produced by abdominal aneurysm repair and prior colectomy.
8. To understand the etiologies causing failure of graft incorporation and perigraft fluid collections including infection, seroma, hematoma, and lymphocele.
9. To recognize anatomic and hemodynamic conditions which can result in graft occlusion including myointimal hyperplasia, atherosclerotic disease progression, anastomotic false aneurysm formation, graft entrapment, low flow, thromboembolism, hypercoagulable states, and infections.
10. To understand the etiologic differences between immediate and late graft occlusions.
11. To define the incidence and mechanisms of prosthetic graft dilatation.
12. To understand the expected incidence and etiologies of wound healing complications including hematoma, infection, and lymphocele.
13. To recognize non-vascular complications associated with arterial therapy including cardiac ischemia, renal failure, and neurologic deficits.
14. To understand the normal arterial circulation of the spinal cord and the pathophysiology of paraplegia caused by spinal cord ischemia.

### II. Diagnostic Evaluation

#### Pseudoaneurysms

1. To recognize the clinical manifestations of pseudoaneurysm following arteriography, percutaneous transluminal angioplasty, and bypass grafting.
2. To define the appropriate diagnostic evaluation of pseudoaneurysm including the use of duplex ultrasound, computed tomography, magnetic resonance imaging, and arteriography.
3. To recognize the operative findings of infected anastomotic false aneurysm.

#### Aortoenteric Fistulae/Erosions

1. To understand characteristic symptoms and signs of secondary aortoenteric fistula/erosion including prior aortic graft implantation, herald gastrointestinal bleeding, fever, and concomitant anastomotic false aneurysm.
2. To define the appropriate diagnostic evaluation of suspected secondary aorto- or graft-enteric fistula including upper endoscopy, anatomic imaging techniques (CT, MRI, arteriography), and radionuclide functional scans.
3. To understand the role of operative graft exploration in patients with recurrent GI bleeding and normal GI endoscopy.

### Vascular Graft Infections

1. To define the epidemiology of prosthetic graft infection.
2. To understand the characteristic signs and temporal presentation of acute versus late-appearing graft infections including sepsis, GI or perigraft bleeding, fever, malaise, false aneurysm, abdominal, back, or groin pain.
3. To understand the usefulness of various microbiologic culture (agar media, broth media) and recovery (swap culture, biomaterial culture, CT-directed aspiration) techniques in the diagnosis or confirmation of graft infection.
4. To understand the parameters of serologic testing that support the clinical diagnosis of vascular graft infection.
5. To define the appropriate diagnostic evaluation of suspected graft infection including microorganism recovery techniques, functional and anatomic graft imaging, and arteriography.

### Colon Ischemia after Aortic Surgery

1. To understand the characteristic initial signs and symptoms suggestive of colon ischemia
2. To define pre- post-operative clinical conditions that may predispose to colon ischemia after after surgery including visceral occlusive disease (meandering mesenteric artery), prior color surgery, ligation of inferior mesenteric artery, ruptured abdominal aortic aneurysm, postoperative shock.
3. To understand the usefulness of Doppler ultrasound and photoplethysmography in the operative diagnosis of colon ischemia.
4. To define the appropriate diagnostic evaluation for suspected colon ischemia following aortic surgery including the use of rigid and flexible sigmoidoscopy, colonoscopy, and operative exploration.
5. To describe the endoscopic features of the severe and mild (reversible) forms colon ischemia after aortic surgery.

### Occluded Prosthetic Grafts

1. To recognize the symptoms and signs of limb ischemia associated with graft thrombosis.
2. To understand the role and the interpretation of noninvasive vascular testing techniques used for the diagnosis of graft thrombosis including Doppler-derived limb blood pressure measurements, velocity waveform analysis, pulse volume recordings, and duplex scanning, .
3. To define the appropriate diagnostic evaluation of graft occlusion based on severity of limb ischemia.
4. To describe the angiographic features of graft occlusion which indicate embolic versus thrombotic occlusion, and the potential for catheter-directed thrombolysis as a treatment option.

### Perigraft Seroma and Graft Dilatation

1. To define the clinical presentation of perigraft seroma and graft dilatation including symptoms, signs, and postoperative appearance time.
2. To understand the usefulness imaging techniques (ultrasound, CT, MRI, arteriography) in the diagnosis of etiologic factors associated with failure or graft incorporation.
3. To describe the features of aspirated perigraft fluid which distinguish between chronic perigraft seroma and low-grade graft infection caused by S. epidermidis.
4. To understand the graft types associated with dilatation.

### Wound Complications

1. To define the incidence and clinical manifestations associated with wound hematoma, infection, lymphocele, and dermal necrosis following arterial surgery.
2. To define the classification of wound infection following arterial bypass grafting.
3. To define the essentials of diagnosis to distinguish infectious from non-infectious wound complications.

### Non-Vascular Complications

1. To understand the clinical symptoms and signs, and ECG features of cardiac ischemic.
2. To define the parameters of serologic and urine testing that characterize acute renal failure.
3. To understand the clinical symptoms and signs of neurologic deficit associated with spinal chord ischemia, injury to peripheral nerves, and cauda equina syndromes.
4. To define the appropriate evaluation of paraplegia following aortic surgery.

### III. Treatment

#### Pseudoaneurysm

1. To define the anatomic features of false aneurysms which should be repaired.
2. To understand techniques for surgical exposure and proximal control of aortic, femoral, and other peripheral artery false aneurysms, including the use of balloon-tipped catheters to prevent backbleeding.
3. To define the role of duplex-guided ultrasound for the treatment of common femoral artery pseudoaneurysms following diagnostic arteriography or percutaneous endovascular procedures.
4. To understand the role of interposition grafting to normal artery wall in the treatment anastomotic false aneurysm.

#### Aortoenteric Fistulae/Erosions

1. To understand the role of staged-remote versus immediate-sequential bypass in treatment of aorto-enteric fistula based on severity of GI bleeding and degree of systemic sepsis.
2. To be familiar with surgical techniques involved in ex-situ bypass, total and partial graft excision, restoration of GI tract continuity, and in situ graft replacement using autologous venousgraft, endarterectomized arteries, allograft, and antibiotic-bonded vascular prostheses.
3. To be familiar with surgical techniques of aortic ligation including treatment or aortic sepsis involving the renal or visceral arteries.
4. To define the nature and duration of antibiotic therapy associated with treatment of secondary graft-enteric fistulae/erosions.
5. To define the follow-up of patients treated or aortoenteric fistula/erosion.

#### Vascular Graft Infections

1. To understand the role local treatment and other graft preservation techniques, including muscle flap coverage, in the treatment of exposed arterial grafts and graft infections without anastomotic involvement.
2. To understand the usefulness of in situ graft replacement techniques using autologous, allograft, and vascular prosthetic grafts in selected patients with vascular graft infections, including selection of treatment method based on clinical manifestations, microbiology, and operative findings.
3. To be familiar with antibiotic therapy based on susceptibility testing in the treatment of arterial graft infections.
4. To be familiar with surgical techniques for excision and ex-situ bypass of infected aortic, peripheral, and carotid arterial reconstructions/bypass grafts.
5. To understand the role of graft excision and arterial ligation in patients with graft infection and adequate collateral circulation.
6. To be familiar with surgical techniques for the treatment of aortic stump sepsis or disruption.
7. To define the expected outcome of patients treated for aortic, infrainguinal, or carotid graft infections.

#### Colon Ischemia after Aortic Surgery

1. To be familiar with criteria for IMA re-implatation during aortic surgery.
2. To understand the role and technique of colon resection in treatment of severe ischemia.
3. To define the treatment and follow-up of mild colon ischemia following aortic surgery.

#### Occluded Prosthetic Grafts

1. To be familiar with surgical techniques useful in the treatment of immediate versus late graft occlusions.

2. To define the role of thrombolysis versus surgical intervention for graft occlusion/thrombosis.
3. To define the indications for graft thrombectomy and revision versus graft replacement.
4. To define the role of endovascular techniques (angioplasty, PTA, stent placement) as adjuncts to graft revision procedures.
5. To be familiar with extra-anatomic bypass grafting techniques in treatment of aortofemoral graft limb occlusion.
6. To understand the role of anti-thrombotic therapy in treatment of graft thrombosis.

#### Perigraft Seroma and Graft Dilatation

1. To be familiar with graft replacement techniques as treatment for perigraft seroma and graft structural failure.
2. To understand the importance of microbiologic recovery techniques, including broth culture of graft material, to exclude a biofilm infection.
3. To define the surveillance of prosthetic grafts following implantation to diagnose dilatation, failure of graft incorporation/healing, and anastomotic false aneurysm.

#### Wound Complications

1. To understand the role of prophylactic antibiotics in the prevention wound and graft infections.
2. To understand the standard surgical principles used to treat wound necrosis, hematoma, and infection.
3. To be familiar with non-surgical and surgical techniques useful in the treatment of lymph fistula, lymphocele, and postoperative lymphoedema.

#### Nonvascular Complications (Cardiac, Renal, Neurologic)

1. To understand the role of pre-operative testing, intra-operative monitoring, and post-operative measures to prevent cardiac ischemia.
2. To be familiar with renal preservation techniques associated with aortic and renal surgery.
3. To be familiar with techniques to improve spinal chord perfusion during aortic surgery.

#### References

1. Complications in Vascular Surgery. Bernhard VM and Towne JB (eds), St Louis: Quality Medical Publishing, 1991.
2. Management of Infected Arterial Grafts. Calligaro KD and Veith FJ (eds), St Louis: Quality Medical Publishing, 1994.
3. Brewster DC, et al. Reoperation for aortofemoral graft limb occlusion: Optimal methods and long-term results. *J Vasc Surg* 1987;5:363.
4. Reilly LM et al. Improved management of aortic graft infections: the influence of operation sequence and staging. *J Vasc Surg* 1987;5:421.
5. Hobson RW, et al. Assessment of colon ischemia during aortic surgery by Doppler ultrasound. *J Surg Res* 1976;20:231.
6. Paul SD, Eagle KA. Modalities for assessment of cardiac risk in vascular surgery. In Callow AD and Ernst CB (eds), Stanford, CN: Vascular Surgery: Theory and Practice, 1995, p 783.
7. Safi HJH, et al. Neurological deficit in high risk patients with thoracoabdominal aortic aneurysms: the role of cerebral spinal fluid drainage and distal aortic perfusion. *J Vasc Surg* 1994; 19:236.
8. Bergamini TM, et al. Infection of vascular prostheses caused by bacterial biofilms. *J Vasc Surg* 1988; 7:21.
9. Kuestner LM, et al. Secondary aortoenteric fistula: contemporary outcome using extra-anatomic bypass and infected graft excision. *J Vasc Surg* 1995; 21:184.
10. Berlauk JF, et al. Preoperative optimization of cardiovascular hemodynamics improves outcome in peripheral vascular surgery. *Ann Surg* 1991; 214:289.
11. Blumberg RM, et al. Perigraft seromas complicating arterial grafts. *J Cardiovasc Surg* 1983; 24:372.

12. Watanabe T, et al. Failure of Dacron arterial prostheses caused by structural defects. *J Cardiovasc Surg* 1983; 24:95.
13. Schellack J, et al. Femoral anastomotic aneurysms: a continuing challenge. *J Vasc Surg* 1987; 6:308.

## 11. Management of Vascular Trauma

David Rosenthal, M.D., Robert Batson, M.D., Joseph Mills, M.D.

### I. Etiology and Pathophysiology

1. To understand the mechanism of vascular injury to the upper extremity, thoracic aorta, abdominal aorta and its branches, and lower extremities.
2. To recognize the clinical importance of penetrating vascular trauma (penetrating objects), significance of different gunshot wounds (high/low velocity) and the blunt or crush injury to the vascular system.
3. To define how vascular reconstructive procedures and the failure of these procedures affect the circulatory system.
4. To understand the mechanism of iatrogenic vascular injury and its prevention.

### II. Diagnostic Evaluation

1. To understand the characteristic signs and symptoms of acute vascular compromise.
2. To demonstrate an understanding of the wounding mechanism, assessment of the wound and characteristic findings of the affected extremity distal to the wound and associated injuries.
3. To understand the usefulness of alternative imaging techniques (ie two plane x-ray, Doppler/duplex color flow ultrasonography, venography, angiography, MRI and CT scans) in the management of vascular trauma.
4. To define the characteristic diagnostic finding of imaging techniques in vascular trauma.

### III. Acute Arterial Injuries

1. To understand the characteristic signs and symptoms of acute arterial injury.
2. To define the clinical features of major arterial injury.
3. To understand the indications for noninvasive (Doppler or duplex color flow ultrasonography CT, MRI) and invasive (arteriography, venography) diagnostic studies.
4. To define the preoperative assessment and management of the patient with a major arterial injury.
5. To understand the operative management of acute arterial injury and the management of concomitant venous or visceral injuries.
6. To define the operative approach for specific arterial injuries (ie left and right subclavian).
7. To understand the management of postoperative complications and the management of associated injuries.

### IV. Venous Injuries

1. To understand the characteristic signs and symptoms of acute venous injury.
2. To define the clinical features of major venous injury.
3. To understand the indications for noninvasive (Doppler or duplex color flow ultrasonography CT, MRI) and invasive (venography) diagnostic studies.
4. To define the preoperative assessment and management of the patient with a major venous injury.
5. To understand the operative management of combined arterial and venous injuries, technical management of venous injuries (ie ligation, lateral suture repair, end-to-end anastomosis, venous patch graft or venous replacement graft).
6. To define operative approach and appropriate management of specific major venous injuries (ie management of retro hepatic IVC, subclavian vein).
7. To understand the management of postoperative complications, and associated injuries.

### V. Arteriovenous Fistulas(AVF)

1. To understand the characteristic signs and symptoms of AVFs.
2. To understand the mechanism of injury associated with traumatic AVFs.
3. To define the pathophysiology of AVFs (ie peripheral vascular resistance, heart rate, stroke volume, cardiac output and blood pressures).
4. To understand the indications for noninvasive and invasive diagnostic studies.

5. To define and understand treatment options (ie invasive radiologic procedures, endovascular procedures, and operative techniques).

#### VI. Iatrogenic Injuries

1. To define the mechanism of the iatrogenic injury.
2. To understand the clinical features associated with the iatrogenic injury.
3. To understand the indications for noninvasive and invasive diagnostic studies suspected iatrogenic injury.
4. To define the indications for nonoperative vs. operative treatment of iatrogenic injury.
5. To understand the management and potential complications associated with an iatrogenic injury.

#### VII. Concomitant Fracture and Neurologic Injuries

1. To understand the characteristic signs and symptoms of associated fractures and neurologic injuries with vascular trauma.
2. To understand the anatomic relations with fractures, neurologic injury and the vascular system.
3. To define the mechanism of injury from fracture, dislocation, or subluxation.
4. To understand the influence of penetrating, blunt and crush injuries on the vascular system.
5. To define the noninvasive and invasive diagnostic tests associated with fracture and neurologic injuries.
6. To define associated reconstructive procedures associated with fracture, neurologic injury and the vascular system.
7. To understand the postoperative management of the patient with combined vascular, fracture, or neurologic injury.

#### VIII. Nonoperative Management of Vascular Injuries

1. To define the clinical criteria and indications for nonoperative versus operative management of patients with vascular injuries.
2. To define the clinical pathology and mechanism of injury (penetrating, crush, blunt) associated with combined vascular and visceral injuries.
3. To define and understand the surgical anatomy in relationships of the abdominal aorta and its major branches to the abdominal organs.
4. To define the role of the surgical technique (ie x-rays, peritoneal lavage, laparoscopic assessment, systoscopy, proctosigmoidoscopy, IVP, arteriography, etc) with suspected vascular and visceral injury.
5. To define the operative management of the patient with combined vascular and visceral injury.
6. To demonstrate an understanding of postoperative care for critically ill patients with combined vascular and visceral injuries, potential complications and their appropriate management.

#### References

##### Thoracic/Mediastinal

1. Eddy AC, Rusch VW, Marchioro T, Ashbaugh D, Verrier ED, Dillard D. Treatment of traumatic rupture of the thoracic aorta. *Arch Surg* 1990; 125:1351-56.
2. Richardson JD, Flint LM Jr, Snow NJ, Gray LA, Trinkle JK. MANAGEMENT of transmediastinal gunshot wounds. *Surgery* 1981; 90:671-76.
3. Weaver FA, Suda RW, Stiles GM, Yellin AE. Injuries to the ascending aorta, aortic arch and great vessels. *Surg Gynecol Obstet* 1989; 169:27-31.

##### Carotid/Subclavian/Vertebral

1. Brown MF, Graham JM, Feliciano DV, Mattox KL, Beall AC, DeBaakey ME. Carotid artery injuries. *Am J Surg* 1982; 144:748-753.
2. Landreneau RJ, Whigelt JA, Megison SM, Meier DE, Fry WJ. Combined carotid-vertebral arterial trauma. *Arch Surg* 1992; 127:301-4.
3. Hiatt JR, Busuttill RW, Wilson SE. Impact of routine arteriography on management of penetrating neck

injuries. *J Vasc Surg* 1984; 6:860-66.

4. Phillips EH, Rogers WF, Gaspar MR. First rib fractures: Incidence of vascular injury and indications for angiography. *Surgery* 1981; 89:42-7.
5. Perry MO, Snyder WH, Thal ER. Carotid artery injuries caused by blunt trauma. *Ann Surg* 1980; 192:74-7.
6. Krajewski WJ Jr, Hertzner NR. Blunt carotid artery trauma. *Ann Surg* 1980; 191:341-46.
7. Liekweg WJ Jr, Greenfield LJ. Management of penetrating carotid artery injury. *Ann Surg* 1978; 188:587-92.
8. Ledgerwood AM, Mullins RJ, Lucas CE. Primary repair versus ligation for carotid artery injuries. *Arch Surg* 1980; 115:488-93.

#### Renal

1. Brown MF, Graham JM, Mattox KL, Feliciano DV, DeBakey ME. Renovascular trauma. *Am J Surg* 1980; 140:802-5.
2. Ivatury RR, Zubiwski R, Stahl WM. Penetrating renovascular trauma. *J Trauma* 1989; 29:1620-3.
3. Barlow B, Gandhi R. Renal artery thrombosis following blunt trauma. *J Trauma* 1980; 20:614-7.

#### Combined Orthopedic/Vascular Injuries

1. Jones RE, Smith EC, Bone GE. Vascular and orthopedic complications of knee dislocation. *Surg Gynecol Obstet* 1979; 149:554-8.
2. Rich NM, Metz CW, Hutton JE Jr, Baugh JH, Hughes CW. Internal versus external fixation of fractures with concomitant vascular injuries in Vietnam. *J Trauma* 1971; 11:463-73.

#### Extremities

1. Feliciano DV, Herskowitz K, O’Gorman RB, Cruse PA, Brandt ML, Burch JM, Mattox KL. Management of vascular injuries in the lower extremities. *J Trauma* 1988; 28:319-27.
2. Peck JJ, Eastman B, Bergan JJ, Sedwitz MM, Hoyt DB, McReynolds DG. Popliteal vascular trauma. *Arch Surg* 1990; 125:1339-44.
3. Lim LT, Michuda MS, Flanigan DP, Pankovich A. Popliteal artery trauma: 31 consecutive cases without amputation. *Arch Surg* 1980; 115:1307-13.
4. Roberts RM, String ST. Arterial injuries in extremity shotgun wounds: Requisite factors for successful management. *Surgery* 1984; 96:902-7.
5. Cikrit DF, Dalsing MC, Bryant BJ, Lalka SG, Sawchuck AP, Schulz JE. An experience with upper-extremity vascular trauma. *Am J Surg* 1990; 160:229-33.
6. Bunt TJ, Malone JM, Moody M, Davidson J, Karpman R. Frequency of vascular injury with blunt trauma-induced extremity injury. *Am J Surg* 1990; 160:226-8.

#### Venous Injury

1. Petersen Sr, Sheldon GF, Lim RC Jr. Management of portal vein injuries. *J Trauma* 1979; 19:616-20.
2. Rich NM. Principles and indications for primary venous repair. *Surgery* 1982; 91:492-6.
3. Wilson RF, Wienek RG, Balog M. Factors affecting mortality rate with iliac vein injuries. *J Trauma* 1990; 30:320-3.
4. Rich NM, Hobson RW, Wright CB, Fredde CW. Repair of lower extremity venous trauma: a more aggressive approach required. *J Trauma* 1974; 14:639-52.

#### Diagnostic Studies

1. Francis H, Thal ER, Weigelt JA, Redman HC. Vascular proximity: is it a valid indication for arteriography in asymptomatic patients? *J Trauma* 1991; 31:512-14.
2. Johansen K, Lynch K, Paun M, Copass M. Noninvasive vascular tests reliably exclude occult arterial

trauma in injured extremities. J Trauma 1991; 31:515-22.

3. Richardson JD, Flint LM Jr. Penetrating arterial trauma. Analysis of missed vascular injuries. Arch Surg 1987; 122:678-83.

## 12. Venous Thromboembolic Disease

Anthony J. Comerota, M.D., H. Edward Garrett, Jr., M.D., Richard Welling, M.D.

### I. Etiology, Risk Factors, Epidemiology and Pathophysiology

1. To understand that Rudolf Virchow, the Father of cellular pathology, wrote the classic triad of stasis, hypercoagulable state and vein wall damage leading to venous thrombosis.
2. To understand that all three elements can be involved in patients undergoing elective operations, causing postop DVT remote from the operative wound.
3. To understand that risk factors are quantitative and that increasing the number of risk factors increases the likelihood of venous thromboembolic complications.
4. To understand that not all risk factors are created equal. Malignancy, older age, obesity, long bone fractures, joint replacement, pelvic operations and a previous history of DVT/PE carry more weight (and higher risk) than other considerations.
5. To be familiar with the known hypercoagulable states, and to understand the relative frequency, mechanism of action and treatment of each. (These include: anticardiolipin/antiphospholipid antibodies, lupus anticoagulant, protein C and protein S deficiency, antithrombin III deficiency, hyperfibrinogenemia, plasminogen deficiency, factor V Leiden mutation (activated protein C resistance), heparin induced thrombocytopenia, Coumadin (warfarin) induced skin necrosis.
6. To realize that pulmonary embolism is the most common preventable cause of death in hospitalized patients.
7. To understand that many patients, and perhaps a majority, receive inadequate DVT prophylaxis.
8. To understand the alterations of coagulation which occur during pregnancy.

### II. Spectrum of Venous Thrombosis

1. To understand that asymptomatic DVT can be dangerous (80% of fatal pulmonary emboli occur in patients who do not carry the diagnosis of acute DVT).
2. To understand that 20-30% of isolated calf DVT will extend if untreated.
3. To understand that the superficial femoral vein is actually the main deep vein of the thigh.
4. To appreciate that as an increasing number of segments are involved with venous thrombosis, the clinical picture of acute DVT is increasingly severe and the more problematic the post-thrombotic sequelae.
5. To understand that phlegmasia alba and phlegmasia cerulea dolens refer to the clinical findings resulting from iliofemoral DVT, not that the underlying etiology is different.
6. To appreciate that venous gangrene is not equivalent to phlegmasia cerulea dolens.
7. To appreciate the difference that extensive greater saphenous thrombosis is best treated by ligation and stripping whereas, extensive greater saphenous thrombophlebitis is best treated by ligation of the saphenofemoral junction, warm soaks, compression and nonsteroidal anti-inflammatory agents.
8. To appreciate that short segment distal superficial disease is best treated symptomatically.

### III. Diagnosis

#### Goals:

1. To understand that the absence of clinical findings does not exclude deep venous thrombosis.
2. To appreciate that if the thigh is swollen, the common femoral vein and/or iliac veins, or the superficial femoral and profunda must be involved with the thrombotic process, assuming acute DVT is the etiology of swelling.
3. To understand that physiologic tests, including a venous doppler, impedance plethysmography (IPG), phleborheography (PRG), air plethysmography (APG), or any maximal outflow technique cannot detect nonocclusive venous thrombosis.
4. To appreciate that physiologic tests are inadequate for use as screening tests and inadequate as endpoint testing for efficacy of DVT prophylaxis.
5. To appreciate that ascending phlebography is the traditional gold standard for diagnosis of DVT, which is

being replaced by venous duplex imaging.

6. To understand that the primary diagnostic criterion for DVT with ascending phlebography is visualized thrombus. Nonfilling of a deep vein is a secondary criterion.
7. To appreciate that with ascending phlebography artifacts are due to flow voids from nonopacified blood draining from tributaries, external compression, and laminar flow.
8. To know the appropriate indications for evaluation for a hypercoagulable state.
9. To appreciate that in patients with DVT/PE, blood samples drawn for a hypercoagulable evaluation should be obtained before anticoagulation is initiated.
10. To appreciate that a common finding of a patient with lupus anticoagulant (a misnomer) is prolongation of the PTT on a routine screening blood test.
11. To appreciate that the function of activated factor C is to reduce the activity of factor Va and VIIIa.
12. To appreciate that protein C is vitamin K dependent, has a short half-life, and plasma levels are rapidly reduced by warfarin compounds.
13. To appreciate that antithrombin III is also known as heparin cofactor and is lowered by therapeutic levels of heparin.
14. To appreciate that antithrombin IIIa is significantly increased (approximately 750x) with low dose subcutaneous heparin, which is the basis for low dose heparin prophylaxis.
15. To understand that if DVT is suspected in the pregnant woman and the noninvasive test results are equivocal, ascending phlebography should be performed.

#### IV. Treatment

##### Goals:

1. To understand the multiple actions of heparin, the reasons for heparin resistance and the complications of heparin.
2. To understand that platelet counts must be monitored during heparin therapy regardless of the dose or route of administration.
3. To appreciate that the PTT value does not correlate with bleeding complications in patients receiving therapeutic anticoagulation who do not have identifiable comorbidities.
4. To appreciate that early inadequate anticoagulation (sub-therapeutic PTT) increases the risk of recurrent venous thrombosis 15x.
5. To appreciate that warfarin compounds can be started immediately after the heparin is therapeutic.
6. To appreciate that continuous IV heparin is associated with a better therapeutic outcome and fewer bleeding complications than bolus IV or high dose subcutaneous injection.
7. To appreciate that heparin induced thrombocytopenia (HIT) occurs in 4-6% of patients given unfractionated heparin, and is not dose related.
8. To understand that there are two types of HIT, immediate onset and delayed onset (5-10 days), with platelet counts falling to 40% of baseline or less, or absolute platelet counts < 150,000.
9. To understand that HIT is a result of an IgG-Ab to the platelet membrane causing platelet aggregation.
10. To understand that thrombocytopenia in the presence of heparin induced antibodies is associated with an extremely high risk of thrombotic complications, whereas a patient who is antibody positive but does not drop their platelet count does not have an increased risk of thrombotic complications.
11. Once HIT is diagnosed (or suspected), all heparin must be avoided.
12. To understand that HIT occurs significantly less in patients receiving low molecular weight heparin compared to unfractionated heparin.
13. To appreciate that warfarin compounds can produce skin necrosis when given to patients who have a heterozygote protein C deficiency.
14. To understand that in patients with warfarin induced skin necrosis, warfarin compounds cause protein C to drop thereby increasing activity of factors Va and VIIIa, thereby causing increased coagulation.
15. To appreciate that at least six months of oral anticoagulation is required for first time proximal DVT to adequately avoid recurrences.

16. To understand that low molecular weight heparin, given in weight adjusted dose subcutaneously once daily, is at least as effective and possibly more effective as IV unfractionated heparin for acute DVT.
17. To appreciate that the action of low molecular weight heparin is reduction of factor Xa activity, and it does not affect the PTT.
18. To understand the mechanism of action and the relative merits/risks of fibrinolytic therapy for acute deep venous thrombosis.
19. To appreciate that systemic fibrinolytic therapy for iliofemoral DVT is likely to fail, and that catheter-directed intra-thrombus thrombolysis is preferred.
20. To appreciate that venous thrombectomy is an effective option for patients with acute iliofemoral DVT.
21. To appreciate that the current operative technique of venous thrombectomy has improved compared to the early procedures.
22. To understand that a complete preop evaluation of the contralateral iliofemoral system and vena cava is important prior to venous thrombectomy.
23. To appreciate that an on-table completion phlebogram and correction of an underlying iliac vein stenosis is crucial to successful venous thrombectomy.
24. To appreciate that vena caval filters do not "treat acute DVT", they prevent large pulmonary emboli from occurring.
25. To appreciate that a Bird's nest filter is indicated for patients with a large vena cava.
26. To know reasons why warfarin should be avoided during pregnancy.
27. To understand that the indications for vena caval filters during pregnancy are the same as the non-pregnant patients, however, the filter should be placed in the supra-renal position.
28. To understand that those pregnant patients requiring heparin prophylaxis increase their heparin requirements during the second and third trimester.

#### V. Pulmonary Embolism

##### Goals:

1. To appreciate that pulmonary emboli occur without clinical warning in the majority of the patients.
2. To appreciate that the majority of the deaths from pulmonary emboli occur within 1-2 hours of the embolic event, and that untreated pulmonary embolism is associated with a 30% mortality.
3. To understand the typical signs/symptoms and the usual chest x-ray, blood gas and EKG findings in patients with large pulmonary emboli.
4. To appreciate the proper use of ventilation perfusion lung scan, and understand the valuable integration of predictive values based upon clinical suspicion of PE. (PIOPED data)
5. To appreciate that thrombolysis of pulmonary emboli results in better cardiopulmonary hemodynamic parameters than standard anticoagulation.
6. To understand the indications for operative pulmonary embolectomy and to appreciate that patients considered for a pulmonary embolectomy should be offered high dose fibrinolytic therapy first (if there are no contraindications).

##### References

1. Comerota AJ, Katz ML, Grossi RJ et al. The comparative value of noninvasive testing for diagnosis and surveillance of deep vein thrombosis. *J Vasc Surg* 1988;7(1):40.
2. Comerota AJ. Venous Thromboembolism. In: Rutherford R (ed) *Vascular Surgery* fourth edition. Philadelphia, W.B. Saunders Company, 1995.
3. Goldhaber SZ. Thrombolytic Therapy for Pulmonary Embolism. In: Comerota AJ (ed) *Thrombolytic Therapy for Peripheral Vascular Disease*. Philadelphia, JB Lippincott, 1993.
4. Hirsh J, Poller L, Deykin D et al. Optimal therapeutic range for oral anticoagulants. ACCP/NHLBI National Conference on Antithrombotic Therapy. *Chest* 1989;2(Suppl):5S.
5. Hull RD, Raskob GE, Hirsh J et al. Continuous intravenous heparin compared with intermittent subcutaneous heparin in the initial treatment of proximal vein thrombosis. *N Engl J Med* 1986;315:1109.

6. Lindblad B, Sternby NH, Bergqvist D. Incidence of venous thromboembolism verified by necropsy over 30 years. *Br Med J* 1991;302:709.
7. Meissner MH, Manzo RA, Bergelin RO, Strandness DE. Deep venous insufficiency: the relationship between lysis and subsequent reflux. *J Vasc Surg* 1993;18:596-608.
8. Plate G, Einarsson E, Olin P et al. Thrombectomy with temporary arteriovenous fistula in acute iliofemoral venous thrombosis. *J Vasc Surg* 1984;1:867.
9. Shull KC, Nicolaides AN, Fernandes e Fernandes J et al. Significance of popliteal reflux in relation to ambulatory venous pressure and ulceration. *Arch Surg* 1979;114:1304.
10. Togli MR, Weg JG. Current concepts: venous thromboembolism during pregnancy. *N Engl J Med* 1996;335:108-114.
11. National Institutes of Health Consensus Development Conference. Prevention of venous thrombosis and pulmonary embolism. *JAMA* 1986;256:744.
12. The PIOPED Investigators. Value of the ventilation/perfusion scan in acute pulmonary embolism: results of the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED). *JAMA* 1990;263:1753-9.
13. Hirsh J. Heparin. *N Engl J Med* 1991;324:1565-74.
14. Hyers TM, Hull RD, Weg JG. Antithrombotic therapy for venous thromboembolic disease. *Chest* 1995;108:Suppl:335S-351S.
15. Warkentin TE, Levine MN, Hirsh J et al. Heparin-induced thrombocytopenia in patients treated with low-molecular-weight heparin or unfractionated heparin. *N Engl J Med* 1995;332:1330-5.

### 13. **Chronic Venous Insufficiency**

John F. Eidt, M.D., Dhiraj M. Shah, M.D., James N. Thomas, M.D.

#### I. Anatomy & Pathophysiology

1. To review normal venous anatomy: superficial, deep and perforating veins, greater saphenous vein (GSV), lesser saphenous vein (LSV), femoral, popliteal & tibial vessels.
2. To describe the major venous anatomic variants of clinical importance including left sided inferior vena cava, retroaortic and circumaortic left renal vein.
3. To understand normal venous hemodynamics and the derangements associated with chronic venous insufficiency.
4. To review the epidemiology of chronic venous insufficiency.
5. To understand the function of normal venous endothelium and its alteration in chronic venous insufficiency (e.g. production of prostacyclin, plasminogen activator, heparans and thrombomodulin).
6. To outline the major risk factors for venous thrombosis including acquired and hereditary hypercoagulable conditions.
7. To review the postulated consequences of venous thrombosis on normal venous patency and valve function.
8. To explain the relationship between acute deep vein thrombosis and the eventual development of chronic venous insufficiency.
9. To define:
  - Chronic venous insufficiency
  - Varicose veins
  - Perforating veins
  - Telangiectasia
  - Sclerotherapy
  - Lipodermatosclerosis
  - Venous claudication
  - Phlegmasia cerulea dolens
10. To review the postulated chain of events that leads to lipodermatosclerosis and venous ulceration.
11. To understand that chronic venous disease is defined as an abnormally functioning venous system caused by venous valvular incompetence with or without venous outflow obstruction which may affect the superficial venous system, the deep venous system or both.
12. To understand that the term post-thrombotic may be used if the patient has experienced an objectively documented episode of DVT. The term postphlebotic syndrome should not be used because this implies the presence of an inflammatory component that is infrequently confirmed.
13. To review the role of inflammatory cells in the development of venous stasis ulcers.
14. To understand that chronic venous insufficiency can lead to significant morbidity and may be disabling.
15. To differentiate congenital from acquired forms of venous insufficiency.

#### II. Diagnostic Evaluation

1. To review the "CEAP" classification system of chronic venous insufficiency: Clinical condition, Etiology, Anatomic distribution and Pathophysiology.
2. To understand and differentiate the three etiologic categories of venous dysfunction: congenital, primary (acquired, undetermined cause) and secondary (acquired, e.g. post-thrombotic or post traumatic).
3. To differentiate the clinical features of superficial venous insufficiency from deep vein (or combined) insufficiency.
4. To review the noninvasive and invasive evaluation of the venous system including ascending & descending venography, photoplethysmography, air plethysmography, and duplex scanning.
5. To describe the characteristics of venous stasis ulcers and differentiate from other types of ulcers including arterial, neuropathic, malignant, infectious and inflammatory (vasculitis).
6. To differentiate stasis dermatitis from other causes of dermatitis in the lower leg.

### III. Treatment

1. To describe the types of available therapy for superficial venous insufficiency (varicose veins) including elastic stockings, elevation, sclerotherapy, laser treatment, stab evulsion, stripping.
2. To review the strengths and drawbacks of agents used in sclerotherapy including hypertonic saline, sodium tetradecyl sulfate, polidocanol etc.
3. To recognize the relative risks and benefits associated with treatment of varicose veins including DVT, infection, skin slough, etc.
4. To define the principles of non-operative management of lower extremity chronic venous insufficiency: ambulation, elevation, elastic support.
5. To review the technique of ambulatory phlebectomy (microstab evulsion) for varicose veins including the use of tumescent (large volume, low strength) local anesthesia.
6. To review the indications for surgery and surgical options in the treatment of chronic venous insufficiency, varicose veins, venous obstruction and stasis ulceration.
7. To describe the procedures for treatment of valve reflux including valvuloplasty, vein valve autotransplantation and vein segment transposition.
8. To discuss the relative risks and merits of procedures designed to decrease the degree of valve reflux.
9. To describe the procedures designed to treat venous outflow obstruction including autogenous or prosthetic bypass and venous disobliteration.
10. To describe the non-operative management of venous stasis ulcers including UNNA Boot, etc.
11. To review the operative procedures for venous ulceration including subfascial ligation.
12. To outline the technical features of 1) endoscopic subfascial ligation of incompetent ankle perforating veins in the treatment of chronic venous insufficiency and 2) endoscopic excision of varicose veins.
13. To describe the proposed pharmaceutical treatment of venous stasis ulcers: pentoxifyllines, prostaglandins, antibiotics, growth factors, etc.

### References

1. Beebe HG, Bergan JJ, Bergqvist D, et al. Classification and grading of chronic venous disease in the lower limbs--a consensus statement. Organized by Straub Foundation with the cooperation of the American Venous Forum at the 6th annual meeting, February 22-25, 1994, Maui, Hawaii. [Review]. *Vasa* 1995;24(4):313-8.
2. Bergan JJ. New developments in the surgical treatment of venous disease. *Cardiovasc Surg* 1993;1(6):624-31.
3. Caps MT, Manzo RA, Bergelin RO, Meissner MH, Strandness DE, Jr. Venous valvular reflux in veins not involved at the time of acute deep vein thrombosis. *J Vasc Surg* 1995;22(5):524-31.
4. Comerota AJ, Harada RN, Eze AR, Katz ML. Air plethysmography: a clinical review. [Review]. *Intl Ang* 1995;
5. Cordts PR, Hanrahan LM, Menzoian JO, et al. A prospective, randomized trial of Unna's boots versus Duoderm CGF hydroactive dressing in the treatment of venous stasis ulcers. *J Vasc Surg* 1992;15:480-86.
6. Criado E, Johnston GJ. Noninvasive methods of diagnosing venous disease. In: Ernst C, Stanley JC ed. *Current therapy in vascular surgery*. St. Louis: Mosby, 1995: 879-883.
7. Dougherty MJ, Calligaro KD, DeLaurentis DA. Congenitally absent inferior vena cava presenting in adulthood with venous stasis and ulceration: a surgically treated case. [Review]. *J Vasc Surg* 1996;23(1):141-6.
8. Erickson CA, Lanza DJ, Karp DL, et al. Healing of venous ulcers in an ambulatory care program: the roles of chronic venous insufficiency and patient compliance. *J Vasc Surg* 1995;22(5):629-36.
9. Glociczki P, et al. Surgical technique and preliminary results of endoscopic subfascial division of perforating veins. *J Vasc Surg* 1996;23:517-23.
10. Goldman MP. Sclerotherapy & Treatment of varicose and Telangiectatic leg veins. In: Mosby Year Book. St. Louis: 1991:
11. Hirsh J. Heparin. *NEJM* 1991;324:1565-74.

12. Hirsh J. Oral anticoagulation therapy. *NEJM* 1991;324:1865-75.
13. Iafrati MD, Welch H, O'Donnell TF, Belkin M, Umphrey S, McLaughlin R. Correlation of venous noninvasive tests with the Society for Vascular surgery/international society for cardiovascular surgery clinical classification of chronic venous insufficiency. *J Vasc Surg* 1994;19(6):1001-7.
14. Johnson BF, Manzo RA, Bergelin RO, Strandness DE, Jr. Relationship between changes in the deep venous system and the development of the post-thrombotic syndrome after an acute episode of lower limb deep vein thrombosis: a one to six year follow-up. *J Vasc Surg* 1995;21(2):307-12.
15. Kistner RL, Eklof B, Masuda EM. Deep venous valve reconstruction. [Review]. *Cardiovasc Surg* 1995;3(2):129-40.
16. Labropoulos N, Delis K, Nicolaidis AN, Leon M, Ramaswami G. The role of the distribution and anatomic extent of reflux in the development of signs and symptoms in chronic venous insufficiency. *J Vasc Surg* 1996;23(3):504-10.
17. Labropoulos N, Delis KT, Nicolaidis AN. Venous reflux in symptom-free vascular surgeons. *J Vasc Surg* 1995;22(2):150-4.
18. Labropoulos N, Giannoukas AD, Nicolaidis AN, Ramaswami G, Leon M, Burke P. New insights into the pathophysiologic condition of venous ulceration with color-flow duplex imaging: implications for treatment? *J Vasc Surg* 1995;22(1):45-50.
19. Labropoulos N, Leon M, Nicholaides A, et al. Venous reflux in patients with previous deep venous thrombosis correlation with ulceration and other systems. *J Vasc Surg* 1994;20:20-26.
20. Labropoulos N, Leon M, Volteas N, Nicolaidis AN. Acute and long-term effect of elastic stockings in patients with varicose veins. *Intl Angio* 1994;13(2):119-23.
21. Leu AJ, Leu HJ, Franzeck JK, Bollinger A. Microvascular changes in chronic venous insufficiency--a review. [Review]. *Cardiovasc Surg* 1995;3(3):237-45.
22. Linton RR. The communicating veins of the lower leg and the operative technique for their ligation. *Ann Surg* 1938;107:582-93.
23. Markel A, Manzo RA, Bergelin RO, Strandness DE, Jr. Incidence and time of occurrence of valvular incompetence following deep vein thrombosis. *Wiener Medizinische Wochenschrift* 1994;144(10-11):216-20.
24. Markel A, Meissner MH, Manzo RA, Bergelin RO, Strandness DE, Jr. A comparison of the cuff deflation method with Valsalva's maneuver and limb compression in detecting venous valvular reflux. *Arch Surg* 1994;129(7):701-5.
25. Masser PA, DeFrang RD, Gostile A, et al. Choice of tests for vascular laboratory evaluation of venous reflux. *J Vasc Tech* 1994;18:165-169.
26. Mayberry JC, Moneta GL, Taylor LM, Porter JM. Non-operative treatment of venous stasis ulcers. In: Bergan JJ, Kistner RL ed. *Atlas of venous surgery*. Philadelphia: W.B.Saunders, 1992: 81.
27. Naschitz JE, Yeshurun D, Schwartz H, et al. Pathogenesis of lipodermatosclerosis of venous disease: the lesson learned from eosinophilic fasciitis. *Cardiovasc Surg* 1993;1(5):524-9.
28. Neglen P, Ragu S. Deterioration of outflow obstruction in CVI. *J Vasc Surg* 1993;17:583-589.
29. Nicolaidis AN, et al. The relation of venous ulceration with ambulation venous pressure measurements. *J Vasc Surg* 1993;17:414-419.
30. Nicolaidis AN, et al. Classification and grading of chronic venous disease in the lower extremity: A consensus statement. *Vascular Surgery* 1996;30:5-11.
31. O'Donnell T, McEnroe CS, Mackey WC, et al. Correlation of clinical findings with venous hemodynamics in 386 patients with chronic venous insufficiency. *Am J Surg* 1986;156: 148-56.
32. Pappas PJ, Teehan EP, Garcia A, et al. Diminished mononuclear cell function is associated with chronic venous insufficiency. *J Vasc Surg* 1995;22(5):580-6.
33. Porter JM. Reporting standards in venous disease: An update. *J Vasc Surg* 1995;21:635-45.
34. Raju S, Fredericks R. Valve reconstruction procedures for non-obstructive venous insufficiency: Rationale, techniques and results in 107 procedures with two- to eight year follow-up. *J Vasc Surg* 1988;7:301-310.

35. Rutgers PH, Kitslaar PJ. Randomized trial of stripping versus high ligation combined with sclerotherapy in the treatment of the incompetent greater saphenous vein. *Am J of Surg* 1994;168(4):311-5.
36. Struckman JR, Nicolaides AN. Flavonoids. A review of the pharmacology and therapeutic efficacy of Daflon 500 mg in patients with chronic venous insufficiency and related disorders. [Review]. *Angiology* 1994;45(6):419-28.
37. Van Bemmelen PS. Evaluation of the patient with chronic venous insufficiency: old and emerging technology i. In: Strandness DE, Jr., Van Breda A ed. *Vascular Diseases: Surgical & Interventional Therapy*. New York: Churchill Livingstone, 1994: 941.
38. van Ramshorst B, van Biemelen PS, Hoeneveld H, Eikelboom BC. The development of valvular incompetence after deep vein thrombosis: a follow-up study with duplex scanning. *J Vasc Surg* 1994;19(6):1059-66.
39. Wittens CH, Pierik RG, Van Urk H. The surgical treatment of incompetent perforating veins. [Review]. *Eur. J Vasc & Endo Vasc Surg* 1995;9(1):19-23.

## **14. Lymphedema**

Louis M. Messina, M.D., Robert B. Smith, M.D.

### I. Anatomy

1. To know the anatomy of the adult lymphatic system from the level of the terminal lymphatics to the cisterna chyli
2. To know the microscopic anatomy of the lymphatic capillaries and conducting lymph vessels and specifically how they differ from veins and arteries.
3. To understand the physiological determinants of lymph flow, including intrinsic contractility of lymph vessels, increased interstitial pressure, muscular activity, arterial pressure, respiratory pressure, and gravity.
4. To know the major differences that distinguish the physiology of the lymphatic system from the venous system.
5. To know the major purposes of the lymphatic system, including transport of interstitial fluid and macromolecular proteins lost from capillaries, bacterial and fungal infections, foreign material.
6. To know the classification of causes of lymphedema, including:
  - A. Primary lymphedema, Congenital (onset before one year of age)
    1. Non-familial
    2. Familial (Milroy's Disease)
  - B. Primary lymphedema, Praecox (onset 1 to 35 years of age)
    1. Non-familial
    2. Familial (Meige Disease)
  - C. Primary lymphedema, Tarda (onset after 35 years of age)
  - D. Secondary lymphedema, including filariasis, lymph node excision and radiation, tumor invasion, infection, and trauma
    1. To understand the functional classification of lymphedema based on the underlying lymphatic anatomy as determined by lymphangiography.
    2. To understand how lymphedema develops the compensatory mechanisms that develop in response to increased interstitial pressure, and the tissue effects of chronic lymphatic obstruction including impaired immune cell trafficking, lymphatic obstruction, and chronic intestinal inflammation.
    3. To understand the secondary consequences of long-standing lymphedema: infection, fibrosis, and neoplasia.
    4. To understand the functional and anatomical abnormalities that cause chylous disorders.
    5. To understand the consequences of the loss of chyle into body cavities or through a chylocutaneous fistula.

### II. Diagnosis of Lymphedema

1. To understand classic clinical classifications of lymphedema based on etiology (primary vs secondary), genetics (familial vs sporadic), and time of onset.
2. To understand the history and physical findings which enable the clinician to identify the cause and site of lymphatic obstruction.
3. To understand pattern of pain, edema, and skin changes that distinguish lymphedema from other causes of extremity edema.
4. To understand the clinical presentation of complications of chronic lymphedema including infection (fungal and bacterial) and malignancy.
5. To understand the nutritional and immunological consequences of chronic lymphangiectasia with protein-losing nephropathy, chylous ascites, or chylothorax.
6. To understand the accuracy and limitations of the most frequent noninvasive imaging modalities used to evaluate lymphatic disease: lymphoscintigraphy, computed tomography, and magnetic resonance imaging.
7. To understand the technique of lymphoscintigraphy, the features of a normal lymphoscintigram and the

typical scintigraphic findings in primary and secondary lymphedema.

8. To understand the indications, techniques, interpretation and complications of lymphangiograms.

### III. Management of Chronic Lymphedema

1. To understand the techniques of non-operative management of primary and secondary lymphedema.

2. To know the mechanisms of action and effectiveness/ineffectiveness of pharmacologic agents such as diuretics, benzopyrones, and steroids in the treatment of lymphedema.

3. To understand the mechanical techniques to reduce a limb swelling

A. To understand the technique of limb elevation.

B. To understand the technique, advantages, and disadvantages of manual lymphatic drainage.

C. To understand the technique of intermittent pneumatic compression, including pressure, ratio of compression/decompression, duration of therapy.

D. To understand the technique of intermittent, non-pneumatic high pressure compression

E. To know the role of antibiotics in the treatment and prophylaxis of recurrent cellulitis in patients with chronic lymphedema.

1. To know the techniques for maintenance of limb size including elastic and non-elastic support.

2. To know the indications for surgical management of chronic lymphedema

3. To understand the technique, complication rate, and effectiveness of excisional procedures including the Charles procedure, Thompson's buried dermal flap, suction curettage, and Sistrunk procedures.

4. To know the indications, technique, complications rate, and outcome of direct lymphatic reconstruction such as lymphovenous anastomosis including lymphnodal-venous and lymphvenous procedures.

5. To know the indications, technique, complication rate, and outcome of lymphatic grafting.

6. To know indication, technique, complications rate of indirect lymphatic reconstructions such as the mesenteric bridge operation, omental flap, and autotransplantation of free lymphatic flap.

A. To know the indications, technique, complications, and outcome of procedures for primary chylous disorders.

### References

1. Rudkin GH, Miller TA: Lymphatic Disease. *In* Ernst CB and Stanley JC (eds): Current Therapy in Vascular Surgery. St. Louis, Mosby: 1995, pp 973-978.

2. Goldsmith HS, Holmes W: Secondary Lymphedema. *In* Ernst CB and Stanley JC (eds): Current Therapy in Vascular Surgery. St. Louis, Mosby: 1995, pp 978-982.

3. Gloviczki P: The management of lymphatic disorders. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1883-1888.

4. Witte CL, Witte MH: Lymphodynamics and pathophysiology of lymphedema. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1889-1899.

5. Gloviczki P, Wahner H: Clinical diagnosis and evaluation of lymphedema. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1899-1920.

6. Rooke TW, Gloviczki P: Nonoperative management of chronic lymphedema. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1920-1927.

7. Abdou MS, Ashby ER, Miller TA: Excisional operations for chronic lymphedema. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1928-1936.00

8. Gloviczki P: Lymphatic reconstruction. *In* Rutherford RB (ed): Vascular Surgery. Philadelphia, W.B. Saunders Co.: 1995, pp 1936-1950.

9. Gloviczki P: Physiologic changes in lymphatic dysfunction. *In* White RA and Hollier LH (eds):

Vascular Surgery. Basic Science and Clinical Correlations. Philadelphia, J.B. Lippincott: 1994, pp 293-302.

10. Gloviczki P, Calcagno D, Schirger A, et al: Non-invasive evaluation of the swollen extremity: Experiences with 190 lymphoscintigraphic examinations. *J Vasc Surg* 9:683, 1989.
11. Clouse ME, Wallace S: Lymphatic Imaging. Lymphography, Computed Tomography, and Scintigraphy. 2nd ed. Baltimore, Williams & Wilkins, 1985.
12. Pappas CJ, O'Donnell TF Jr: Long-term results of compression treatment for lymphedema. *J Vasc Surg* 16:555, 1992.
13. Gloviczki P, Fisher J, Hollier LH, et al: Microsurgical lymphovenous anastomosis for treatment of lymphedema: A critical review. *J Vasc Surg* 7:647, 1988.
14. O'Brien BMcC, Mellow CG, Khasanchi RK, et al: Long-term results after microlymphatico-venous anastomoses for the treatment of obstructive lymphedema. *Plast Reconstr Surg* 85:562, 1990.
15. Casley-smith JR, Morgan RG, Piller NB: Treatment of lymphedema of the arms and legs with 5.6-benzo-(alpha)-pyrone. *N Engl J Med* 329:1158, 1993.
16. Browse NL: The diagnosis and management of primary lymphedema. *J Vasc Surg* 3:181, 1986.
17. Thiadens SRJ: Advances in the management of lymphedema. *In* Goldstone J (ed): *Perspectives in Vascular Surgery*. St. Louis, Quality Medical Publishing, 1990, pp 125-141.
18. Kobayashi MR, Miller TA: Lymphedema. *Clin Plast Surg* 14:303, 1987.

## 15. **Extremity Amputation**

Roger T. Gregory, M.D., G. Patrick Clagett, M.D., H. Fabio Giron, M.D.

### I. Anatomy and Pathophysiology

1. To learn the normal anatomy of the extremities including all muscles, nerves, vessels, and bones.
2. To understand the various pathophysiologic conditions which leads to the need for an extremity amputation.

### II. Diagnostic Evaluation

#### Clinical Indications for Amputation

1. To understand when acute ischemia is irretrievable.
2. To understand when chronic ischemia is unacceptable.
3. To define when amputation offers improved quality of life.
4. To be able to recognize when an ischemic limb is a threat to survival.
5. To understand when diabetic foot infections may necessitate amputation despite adequate circulation - the concept of "life threatening infection."
6. To define the role of osteomyelitis in determining the need and type of amputation.

#### Determining the Level of Amputation

1. To understand the importance of proper amputation level selection.
2. To define the methods of determining amputation level by clinical criteria.
3. To define methods of determining amputation level by noninvasive methods.
4. To understand the limits of angiography.

### III. Treatment

#### Lower Extremity Amputation Techniques

1. To understand the basic techniques for toe amputation, ray amputation, transmetatarsal amputation, below knee amputation, above knee amputation and upper extremity amputation.
2. To understand situations when "unusual" amputations may be appropriate, such as Choparts, Lisfranc, Symes, through-knee, hip disarticulation, hemipelvectomy, and, even, hemicorporectomy.
3. To understand the causes of stump failure, including technical problems, inadequate skin and muscle perfusion, hematoma, inadequate flaps, pressure necrosis from transected bone, and infection.

#### Postamputation Care, Prosthetic Management and Rehabilitation

1. To define the differences offered by soft versus rigid dressings.
2. To understand the importance of early mobilization.
3. To achieve a basic understanding of lower extremity prosthetic devices, specifically the pros and cons of immediate versus delayed prosthesis.
4. To understand how amputation technique can impact upon prosthetic application and subsequent rehabilitation.
5. To define goals of rehabilitation with individual capabilities.
6. To understand the importance of communication and participation of a multiple disciplined team approach to the amputee and the special problems presented.
7. To understand the consequences of flexion contracture following amputation.
8. To be able to recognize and manage phantom pain syndromes.

#### References (\*excellent references)

##### Texts

1. Current Therapy in Vascular Surgery, 2nd edition. Ed. Ernst C & Stanley J. Section on Amputation. Philadelphia, BC Decker Inc. 1991. Pp. 690 - 712.

2. \* Vascular Surgery, 4th edition. Ed. Rutherford RB. Philadelphia, WB Saunders Co. Section XIX. Extremity Amputation for Vascular Disease. 1995; Pp. 1951-2033.
3. Tooms RE. Amputation of the Lower Extremity. In Crenshaw AH (ed). Campbell's Operative Orthopaedics. 7th ed. St. Louis, CV Mosby, 1987, vol. 1 Pp. 607-627.
4. \* Malone JM. Lower Extremity Amputation. In Vascular Surgery, 4th ed. Philadelphia, WB Saunders Co. 1993; Pp. 809-853.

#### Journal Articles

1. Couch NP, David JK, Tilney NL, et al. Natural History of the Leg Amputee. *Am J Surg.* 1977; 133:469.
2. Eneroth M, Persson BM. Risk Factors for Failed Healing in Amputation for Vascular Disease. A Prospective, Consecutive Study of 177 Cases. *Acta Orthop Scand.* 1993; 369.
3. Fisher, DF, Clagett P, Fry RE, Humble TH, Fry WJ. One-Stage versus Two-Stage Amputation for Wet Gangrene of the Lower Extremity: A Randomized Study. *J Vasc Surg.* 1988; 8:428.
4. Gibbons G. The Diabetic Foot: Amputations and Drainage of Infection. *J Vasc Surg.* 1987. 5:791.
5. \*Keagy BA, Schwartz JA, Kotb M, Burnham SJ, Johnson G. Lower Extremity Amputation: The Control Series. *J Vasc Surg.* 1986; 4:321.
6. Malone JM, Moore WS, Goldstone J, Malone SJ. Therapeutic and Economic Impact of a Modern Amputation Program. *Ann Surg.* 1979; 189:798.
7. Malone JM, Moore W, Leal JM, Childers SJ. Rehabilitation for Lower Extremity Amputation. *Arch Surg.* 1981. 116:93.
8. \* Malone JM, Anderson CG, Robertson CL, et al. Prospective Comparison of Noninvasive Techniques for Amputation Level Selection. *Am J Surg.* 1987; 154:179.
9. McIntyre KE. Control of Infection in the Diabetic Foot: The Role of Microbiology, Immunopathology, Antibiotics and Guillotine Amputation. *J Vasc Surg.* 1987; 5:787.
10. \*Pinzur MS, Gogtschalk F, Smith, Shanfield S et al. Functional Outcome of Below-Knee Amputation in Peripheral Vascular Insufficiency. A Multicenter Review. *Clin Orthop.* 1993; 286:247.
11. Porter JM, Baur GM, Taylor LM. Lower Extremity Amputations for Ischemia. *Arch Surg.* 1981; 116:89.
12. \*Roon AJ, Moore WS, Goldstone J. Below-Knee Amputation: A Modern Approach. *Am J Surg.* 1977; 138:52.
13. Sherman RA. Stump and Phantom Limb Pain. *Neurol Clin.* 1989; 7:249.
14. Schina MJ, Atnip RG, Healy, Thiele BL. Relative Risks of Limb Revascularization and Amputation in the Modern Era. *Cardiovasc Surg.* 1994; 6:754.
15. Tunis SR, Bass EB, Steinberg EP. The Use of Angioplasty, Bypass Surgery, and Amputation in the Management of Peripheral Vascular Disease. *N Engl J Med.* 1991; 325:556.

## **16. Diagnostic Techniques**

David S. Sumner, M.D., John Blebea, M.D.

### Goals

#### I. History

1. To understand the essential components of a comprehensive vascular history.
2. To recognize symptoms relevant to vascular disease, identify salient points and understand their significance.
3. To use the information to formulate an initial diagnosis and to evaluate the severity of the likely disease process.
4. To identify confounding symptoms of similar nature produced by non-vascular diseases.
5. To obtain historical information pertinent to the evaluation of patients for operation or information that would militate against operative intervention or dictate the choice of therapy.

#### II. Physical Examination

1. To understand the significance of observational signs, such as skin color and texture, swelling, gangrene, and ulcers.
2. To detect and evaluate peripheral pulses, bruits, thrills, skin temperature, edema, tissue turgor, and vascular dimensions.
3. To develop the skills necessary to palpate the abdomen, neck, and extremities in order to localize sites of tenderness and to recognize the presence of masses and abnormal pulsations.
4. To be capable of performing basic neurological evaluations.
5. To interpret physical findings, understand how they contribute to the diagnosis, recognize their limitations, and be aware of other diseases that might mimic the findings.

#### III. Noninvasive Tests

1. To be familiar with commonly used noninvasive instruments and modalities, such as Doppler ultrasound, duplex and color-flow scanning, B-mode imaging, plethysmography (air, mercury, and impedance), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and computerized X-ray tomography (CT), and to understand the basic principles involved in their design and operation.
2. To be familiar with noninvasive pressure measurements (including ankle/brachial indices, segmental pressures, digital pressures), arterial and venous velocity tracings, Doppler frequency spectral analysis, segmental and digital plethysmography, transcutaneous oxygen tension measurements (TcPO<sub>2</sub>), venous outflow plethysmography, calf venous air-plethysmography (Nicolaidis method) and to understand the hemodynamic principles underlying exercise testing (treadmill walking and claudication times, post-exercise ankle pressure) and reactive hyperemia.
3. To understand the physiologic basis of these tests and their limitations, know when to order noninvasive tests, which to select and how to interpret the results.
4. To perform simple noninvasive assessments (such as Doppler venous and arterial surveys and measurement of ABIs) and be able to interpret duplex scans, MRIs, MRAs, and CT scans.

#### IV. Invasive Diagnostic Methods

1. To be highly skilled in the interpretation of angiograms of all arterial and venous segments.
2. To understand the limitations and inherent risks of angiography, be aware of sources of error, and know how to minimize complications.
3. To be adept at obtaining and interpreting intraoperative arteriograms and, whenever possible, to acquire the skills necessary to perform percutaneous arteriography, including catheter manipulation techniques required for selective visualization of visceral and brachiocephalic vessels.
4. To be familiar with the intraoperative use of Doppler and duplex surveys in order to answer specific questions (location and patency of vessels, stenotic sites) and to detect technical errors at the completion of

the reconstruction (residual valves, arteriovenous fistulas, thrombi, anastomotic problems).

5. To be familiar with the intraoperative applications of the angioscope.

6. To perform intraoperative and preoperative percutaneous arterial and venous pressure measurements involving the use of pressure transducers.

7. To have some knowledge of other less frequently performed tests, such as intravascular ultrasound, isotope clearance studies and uptake tests, and scintillation scans.

### Site Specific Goals

#### I. Lower Extremity Arterial Disease

1. To identify the symptoms of intermittent claudication and differentiate them from those of orthopedic or neurological conditions.

2. To recognize symptoms of severe ischemia, (such as rest pain, tissue loss, ulcers, and gangrene); differentiate these symptoms from those of diabetic neuropathy, neurologic, venous, infectious, and other problems; and determine the relative importance of several etiologies when more than one is present.

3. To recognize and differentiate the symptoms and signs of acute arterial occlusion (pain, pallor, numbness, and motor dysfunction) from those of chronic arterial occlusive disease; to assess the urgency of the condition and the threat to limb loss; and to distinguish findings suggestive of embolic occlusion from those of arterial thrombosis.

4. To understand the contribution of noninvasive tests (ABI, plethysmography, duplex surveys, treadmill exercise, and reactive hyperemia) to the diagnosis and know when arteriography, MRA, or other more complex tests are required.

5. Based on the history and physical examination, together with the results of invasive and noninvasive tests, to formulate an accurate diagnosis of arterial disease, identify the location and extent of the obstructive process, assess its severity, and determine the need for and the urgency of interventional therapy.

#### II. Extracranial Cerebrovascular Disease

1. To recognize and evaluate the symptoms and signs of transient hemispheric and nonhemispheric neurologic events and to differentiate them from the symptoms and signs of permanent neurologic damage (stroke) or peripheral neuropathy.

2. To decide, based on their natural history and pathophysiologic behavior, which events require immediate attention.

3. To understand the indications for common noninvasive tests (such as duplex or color-flow scanning), how they may contribute, what their limitations are, and how they are to be interpreted; and to know when to obtain and how to interpret less commonly performed tests, such as transcranial Doppler studies or oculopneumoplethysmography.

4. To know when to order (or not to order) cerebral arteriography, how to read extracranial and intracranial views, how to measure the degree of stenosis, and how to use the findings to select the proper therapeutic approach.

5. To know when to select MRA as an alternative diagnostic method and what its comparative accuracy is compared to arteriography or duplex scanning.

6. To be able to read and interpret CT and MRI scans of the brain, know when to order these studies and how the results influence diagnosis and the need for therapeutic intervention.

7. In asymptomatic patients, to assess cervical bruits, understand their significance, and know which patients without specific signs have a high propensity for extracranial cerebrovascular disease and are likely to benefit from noninvasive diagnostic screening and possible therapeutic intervention.

8. To understand the role of duplex scanning in the follow-up of nonoperated or operated patients with known cerebrovascular disease (to detect recurrent disease or disease progression).

#### III. Brachiocephalic and Upper Extremity Arterial Disease

1. To recognize the signs and symptoms of brachiocephalic disease, including those of hemispheric ischemia,

vertebrobasilar ischemia, and arm claudication and ischemia.

2. To understand the role that brachial, segmental, and digital pressures play in screening for disease and the roles that duplex scanning, arteriography, and MRA play in establishing the diagnosis.

#### IV. Aneurysmal Disease

1. To recognize and interpret the signs and symptoms of abdominal aortic, iliac, femoral, popliteal, visceral, thoracic, carotid, and brachiocephalic aneurysms.
2. To be skilled in the palpation of the abdomen, extremities, and neck in order to recognize pulsatile masses, assess their dimensions, and differentiate those likely to be aneurysms from arterial tortuosity, tumors, or other nonvascular masses.
3. To recognize signs of impending or actual rupture including tenderness, ecchymoses, shock, or other evidence of acute blood loss.
4. To determine the urgency of operative intervention, and decide when ultrasonic, CT, or MRI confirmation is necessary.
5. To be acutely aware of the signs of complications, such as aortic-enteric fistula and high-output cardiac failure due to aorto-caval fistulae.
6. To know the indications for arteriography (or MRA) and how to interpret these studies.
7. To be alert to the indirect signs of aneurysms, such as unexplained embolic phenomena (blue toes or fingers) or sudden ischemia due to acute thrombosis or dissections.

#### V. Visceral Arterial Disease

1. To be familiar with the symptoms of acute visceral arterial occlusion and with the post-prandial pain patterns and weight loss associated with chronic visceral ischemia.
2. To be alert to conditions (such as atrial fibrillation, recent myocardial infarction, arterial dissections) that might lead to acute occlusion of mesenteric arteries.
3. To recognize conditions (such as congestive heart failure) that predispose to nonocclusive mesenteric ischemia.
4. To interpret visceral angiograms and know when these are needed.
5. To understand the role and limitations of duplex scanning in the diagnosis of visceral arterial stenosis.

#### VI. Renal Arterial Disease

1. To recognize the signs and symptoms of renal arterial occlusive disease, as manifested by the onset and severity of hypertension, and be able to determine which patients require further workup.
2. To be familiar with the diagnostic roles of selective renal vein renins, isotope clearance tests, IVP, duplex scanning, and arteriography and know the limitations and predictive value of these tests.

#### VII. Arteriovenous Fistula

1. To be cognizant of the systemic manifestations of large arteriovenous fistulas, including tachycardia, Branham's sign, and high-output cardiac failure and be able to differentiate between acquired and congenital fistulas.
2. To understand the diagnostic significance of a history of penetrating trauma, fractures, back surgery, and vascular catheterization and know the significance of signs, such as birthmarks, limb hypertrophy, unilateral varicose veins, vascular malformations, bruits, and thrills.
3. To be aware of the role that noninvasive pressure measurements and duplex scanning have in establishing a diagnosis, know when to order CT scans, MRI, MRA, or arteriography, and be able to interpret the results.
4. To distinguish between congenital arteriovenous fistulas and primary venous malformations.

#### VIII. Vasospastic Disease

1. To recognize and evaluate the symptoms of episodic digital ischemia provoked by cold exposure (Raynaud's phenomenon) and to be aware of the manifestations of vasospasm, such as changes in skin color

and temperature.

2. To identify signs of underlying autoimmune disease, such as digital atrophy, ulceration, or gangrene and other skin changes.
3. To be aware of the role that noninvasive tests (Doppler surveys, duplex scans, digital pressure measurements, plethysmographic studies, and skin temperature recordings) play in distinguishing purely vasospastic disease from vasospasm superimposed on fixed digital arterial stenoses or occlusions.
4. To know when arteriography is indicated and how to interpret the findings.

#### IX. Acute Venous Thrombosis

1. To recognize the signs and symptoms of acute deep venous thrombosis (DVT) and differentiate them from the signs and symptoms of cellulitis, muscle tears, superficial venous thrombosis, arterial obstruction, and a host of other causes of unilateral limb swelling, edema, pain, and cyanosis.
2. To be aware of the significance of factors predisposing to DVT, such as recent trauma, orthopedic or major abdominal surgery, malignancy or chronic illness, pregnancy, airplane or bus trips, and hypercoagulability.
3. To understand the limitations of the history and physical examination and be aware of the critical role that noninvasive testing (primarily duplex scanning and to a declining extent, hand-held Doppler and impedance plethysmography) now plays in the diagnosis of this disease.
4. To know when phlebograms, magnetic resonance studies, or CT scans are indicated and how to interpret the results.
5. To be aware of the indications for screening asymptomatic high-risk patients for occult DVT and know the limitations of the noninvasive methods used for this purpose.

#### X. Chronic Venous Insufficiency

1. To know the symptoms and signs of varicose veins, chronic venous obstruction, and deep venous incompetence and be able to differentiate these diseases from lymphedema, acute DVT, arteriovenous malformations, and arterial disease.
2. To recognize and evaluate the cutaneous manifestations of chronic venous insufficiency, including lipodermatosclerosis, pigmentation, dermatitis, and ulceration.
3. To know when objective testing is required to establish the diagnosis and understand how duplex scanning may contribute to the anatomic assessment by identifying the sites and distribution of chronic venous obstruction and incompetent venous valves; how air plethysmographic, photoplethysmographic, and other physiologic tests (such as ambulatory venous pressure measurements) may assist in the evaluation and assessment of the severity of physiologic aberrations; and when to order and how to evaluate ascending and descending phlebograms.

#### XI. Lymphedema

1. To be familiar with the historical aspects of lymphedema, noting the time of onset and the presence of previous or coexisting infections, injuries, radiation, or malignancy.
2. To be aware of the significance of the location of swelling, the type of edema (pitting or woody), the presence of cutaneous lichenification, and associated cellulitis.
3. To understand the diagnostic roles of lymphangiography and scintillation scans and when to order and how to interpret these studies.
4. To differentiate between primary and secondary lymphedema and distinguish the various forms of lymphedema from swelling due to chronic venous insufficiency.

#### XII. Trauma

1. To understand the importance of obtaining a history of the injury (whether it was due to blunt or penetrating trauma, gun-shot or knife); of an expeditious physical examination noting the location of the injury (entry and exit points, multiple sites or localized), the presence of external hemorrhage, hematoma,

ecchymoses, or shock, of assessing peripheral pulses, neurologic status, and respiratory compromise, and of identifying associated skeletal or visceral injuries.

2. To know when to obtain Doppler studies, peripheral pressure measurements, duplex scans, transesophageal echo studies, compartmental pressures, CT scans, X-rays, and arteriography.

### XIII. Amputations

1. To recognize the need for amputation and to predict the optimum level based on a history of previous revascularization attempts, etiology of vascular obstruction, the presence of infection, diabetes, or coagulation disorders, location and severity of pain, extent of ulcers or gangrene, presence or absence of pulses, the appearance and temperature of the skin, capillary refill, and overall medical status.

2. To understand the limitations and advantages of using objective tests such as TcPO<sub>2</sub> measurement, isotope clearance, and ankle, segmental, digital, and skin pressures to select the site of amputation.

### References

#### General

1. Abbott WM, Kempczinski RF, Macdonald NR. Core Curriculum for Resident Training in the Vascular Diagnostic Laboratory. Association of Program Directors in Vascular Surgery, 1996.
2. Bernstein EF (ed.) Vascular Diagnosis, 4th ed. St. Louis: CV Mosby, 1993.
3. Kempczinski RF, Yao JST (eds). Practical Noninvasive Vascular Diagnosis (2nd ed). Chicago: Year Book Medical Publishers, Inc., 1987.
4. Hershey FB, Barnes RW, Sumner DS (eds): Noninvasive Diagnosis of Vascular Disease. Pasadena: Appleton Davies, 1984.

#### Peripheral Arterial

1. Mattos MA, van Bemmelen PS, Hodgson KJ, et al. Does correction of stenoses identified with color duplex scanning improve infrainguinal graft patency? *J Vasc Surg* 17:54-66, 1993.
2. Moneta GL, Yeager RA, Antonovic R, et al. Accuracy of lower extremity arterial duplex mapping. *J Vasc Surg* 15:275-84, 1992.
3. Raines JK. The pulse volume recorder in peripheral arterial disease. in Bernstein EF (ed.) Vascular Diagnosis, 4th ed. St. Louis: CV Mosby; 534-543, 1993.
4. Reidy NC, Walden R, Abbott WM, et al. Anatomic localization of atherosclerotic lesions by hemodynamic tests. *Arch Surg* 116:1041-1044, 1981.
5. Rutherford RB, Lowenstein DH, Klein MF. Combining segmental systolic pressures and plethysmography to diagnose arterial occlusive disease of the legs. *Am J Surg* 138:211, 1979.

#### Arteriography, MRI

1. Baum RA, Rutter CM, Sunshine JH, Blebea JS, et al. Multicenter trial to evaluate vascular magnetic resonance angiography of the lower extremity. *JAMA* 274: 875-880, 1995.
2. Hessel SJ, Adams DF, Abrams HL. Complications of angiography. *Radiology* 138:273-281, 1981.

#### Carotid

1. Anderson CM, Saloner D, Lee RE, et al. Assessment of carotid artery stenosis by MR angiography: comparison with x-ray angiography and color-coded Doppler ultrasound. *Am J Neuroradiol* 13:989-1003, 1992.
2. Blackshear WM, Phillips DJ, Thiele BL, et al. Detection of carotid occlusive disease by ultrasonic imaging and pulsed Doppler spectrum analysis. *Surgery* 86:698-706, 1979.
3. Carpenter JP, Lexa FJ, Davis JT. Determination of sixty percent or greater carotid artery stenosis by duplex Doppler ultrasonography. *J Vasc Surg* 22:697-705, 1995.
4. Seiler RW, et al. Cerebral vasospasm evaluated by transcranial ultrasound correlated with clinical grade and CT-visualized subarachnoid hemorrhage. *J Neurosurg* 64:594-600, 1986.

5. Thiele BL, Jones AM, Hobson RW, Bandyk DF, et al. Standards in noninvasive cerebrovascular testing. *J Vasc Surg* 15:495-503, 1992.

#### Abdominal, Visceral

1. Moneta GL, Yeager RA, Dalman R, Antonovic R, et al. Duplex ultrasound criteria for diagnosis of splanchnic artery stenosis or occlusion. *J Vasc Surg* 14:511-20, 1991.
2. Pavone P, DiCesare E, DiRenzi P, et al. Abdominal aortic aneurysm evaluation: comparison of US, CT, MRI, and angiography. *Magn Reson Imaging* 8: 199-204, 1990.
3. Taylor DC, Moneta GL, Kohler TR, et al. Duplex ultrasound in the diagnosis of renal artery stenosis: a prospective evaluation. *J Vasc Surg* 7: 363-369, 1988.

#### Venous

1. Blebea J, Schomaker WR, Hod G, Fowl RJ, Kempczinski RF. Preoperative Duplex venous mapping: A comparison of positional techniques in patients with and without atherosclerosis. *J Vasc Surg* 20: 226-234, 1994.
2. Mattos MA, Londrey GL, Leutz DW, Hodgson KJ, et al. Color-flow duplex scanning for the surveillance and diagnosis of acute deep venous thrombosis. *J Vasc Surg* 15:366-376, 1992.
3. Porter JM, Moneta GL, et al. Reporting standards in venous disease: An update. *J Vasc Surg* 21:635-645, 1995.
4. Rose SC, Zwiebel WJ, Nelson BD, et al. Symptomatic lower extremity deep venous thrombosis: Accuracy, limitations, and role of color duplex flow imaging in diagnosis. *Radiology* 175:639-644, 1990.
5. van Bemmelen PS, Bedford G, Beach K, Strandness DE. Quantitative segmental evaluation of venous valvular reflux with duplex ultrasound scanning. *J Vasc Surg* 10:425-431, 1989.

## 17. **Emerging Technologies**

Thomas F. Panetta, M.D., Teruo Matsumoto, M.D., Rodney A. White, M.D.

### I. General

1. To understand the basic principles of emerging technologies in vascular and endovascular surgery.
2. To develop a working knowledge of the equipment, techniques, technical problems, troubleshooting and recovery techniques.
3. To understand the physical properties of devices including but not limited to wires, catheters, balloons, coils, stents, stent-grafts, filters and delivery systems. To understand the physical properties, basic engineering and evolution of devices as they relate to their clinical applications, implantation, biocompatibility, tissue reactions and interactions, graft-metallurgical interactions, wound healing, limitations and overall use in the treatment of vascular disease.
4. To understand the indications, applications, complications, management and results of imaging modalities, basic techniques, newly developed techniques and implantable devices used to treat vascular disease.

### II. Imaging Modalities

1. To understand radiation physics, safety, risks, cellular effects, somatic effects, dose responses, monitoring, shielding and variations in x-ray equipment as they relate to both patients and personnel including preventative measures for safety.
2. To understand basic principles and equipment used for fluoroscopy and arteriography. To obtain a working knowledge of contrast media, road-mapping, imaging techniques, measurement techniques, parallax, hand and power injection techniques and film sequencing.
3. To understand the basic principles of intravascular ultrasonography (IVUS). To obtain a working knowledge of B-mode imaging, transducers and catheters.
4. To understand the basic principles of angioscopy. To obtain a working knowledge of endoscopes and fiberoptic technology, imaging and irrigating equipment, and channel instrumentation.
5. To understand the techniques used for preoperative, intraoperative and postoperative imaging, measurements and evaluation of endovascular techniques including ultrasonography, magnetic resonance imaging, computerized axial tomography including helical techniques with 3 dimensional reconstructions and angiography.
6. To understand the accuracy, utility, limitations and clinical importance of each modality.

### III. Basic Techniques

1. To obtain a working knowledge of basic endovascular techniques. To understand individual techniques and obtain a knowledge base for standard and emerging technologies.
2. To understand the proper use of needle, catheter, guidewire, dilator and introducer techniques used to gain access to the vascular system and perform vascular interventions.
3. To understand the techniques and mechanisms of angioplasty and atherectomy.
4. To obtain a working knowledge of pharmacological and mechanical methods of thrombolysis.

### IV. Emerging Technologies

1. To obtain a working knowledge of self expanding and balloon expandable intravascular stents. To understand delivery techniques, rationale for use and retrieval/recovery techniques.
2. To understand the various types and uses of occlusion techniques including sclerosing agents and occlusion devices. To obtain a working knowledge of coils, temporary and permanent occlusion balloons, and the variety of covered stent occluding devices.
3. To understand and obtain a working knowledge of endovascular grafts, covered stents and stent-grafts for the treatment of vascular disease. This includes the variety of delivery systems, attachment devices, covered stents, and stent-graft combinations and devices. The values and limitations of each of the available and potentially available devices should be understood.

4. To have a working knowledge of adjunctive interventional procedures required as retrieval, recovery or “bail out” procedures in endovascular surgery including endovascular and open techniques.
5. To understand laparoscopic and laparoscopically assisted vascular techniques for both arterial, venous and adjunctive vascular procedures.
6. To understand the role of brachytherapy in preventing intimal hyperplasia, both as an independent modality or in combination with metallic devices.
7. To understand and have a working knowledge of venous filters and venous devices.

#### V. Clinical Applications

1. To understand and have a working knowledge of endovascular and interventional techniques utilizing percutaneous and surgical access for the diagnosis, management and treatment of traumatic arterial and venous injuries.
2. To understand and have a working knowledge of endovascular and interventional techniques utilizing percutaneous and surgical access for the diagnosis, management and treatment of arterial occlusive disease.
3. To understand and have a working knowledge of endovascular and interventional techniques utilizing percutaneous and surgical access for the diagnosis, management and treatment of aneurysmal disease.
4. To understand and have a working knowledge of endovascular and interventional techniques utilizing percutaneous and surgical access for the diagnosis, management and treatment of cerebrovascular disease.
5. To understand and have a working knowledge of endovascular and interventional techniques utilizing percutaneous and surgical access for the diagnosis, management and treatment of venous disease including arteriovenous malformations.
6. To understand the pathophysiology and management of intimal hyperplasia and recurrent disease after endovascular intervention, endovascular graft placement and insertion of an implantable device.
7. To understand the treatment of acute and chronic complications of endovascular techniques and devices. To understand the pathophysiology and management of arterial injuries, endoleaks, migration, embolization, delivery system failures and attachment device failures.
8. To have a working knowledge of recovery, retrieval and “bail out” procedures for endovascular procedures. This includes both catheter based and surgical procedures.

#### References

1. White RA, Fogarty TJ, Baker WH et al. Endovascular surgery credentialing and training for vascular surgeons. *J Vasc Surg* 17: 1095-1102, 1993.
2. Veith FJ. Transluminally placed endovascular stented grafts (TPEGs) and their impact on vascular surgery. *J Vasc Surg* 20: 855-860, 1994.
3. Clagett GP, Silver D, Veith FJ et al. Impact of new technology on vascular surgery training. *J Endovasc Surg* 2: 133-135, 1995.
4. Clagett GP. Training and credentialing in endovascular surgery for vascular surgeons. In White RA, Fogarty TJ, editors. *Peripheral Endovascular Interventions*, St. Louis, 1996, Mosby.
5. Yao JST, Pearce WH, editors. *Progress in Vascular Surgery*, Stamford, 1997, Appleton & Lange.
6. *Graduate Medical Education Directory 1993-1994*, ed 79, Chicago, 1993, American Medical Association.

## 18. Risk Stratification and Risk Factors

Bruce S. Cutler, M.D., William C. Mackey, M.D.

### I. Cardiac Disease

1. Recognize the frequent association of coronary artery and peripheral vascular disease.
2. Understand the risk factors predictive of perioperative myocardial infarction or cardiac death.
3. Be able to quote basic statistics regarding the frequency of severe CAD in patients with symptomatic peripheral vascular disease.
4. Be familiar with the early and late cardiac mortality figures following major vascular surgery.

### II. Anatomy and Pathophysiology

1. Describe normal coronary artery anatomy
2. Understand the clinical significance of chronic stable angina, unstable angina, recent and remote myocardial infarction and congestive heart failure
3. Understand how an imbalance of myocardial oxygen supply and demand may lead to myocardial ischemia
4. Describe those factors that may lead to an increased demand for myocardial oxygen, and/or a decreased supply that will contribute to myocardial ischemia.
5. Understand the clinical and histological difference between a subendocardial and transmural infarction.
6. Understand the effects of general and regional anesthesia on myocardial oxygen demand and myocardial ischemia.
7. Understand the most important factors present intraoperatively and in the post-operative period that contribute to myocardial ischemia.

### III. Diagnosis

1. Understand the signs and symptoms of chronic stable angina, unstable angina, myocardial infarction and congestive heart failure.
2. Know the risks of operation in a patient with a recent myocardial infarction, unstable angina, or poorly compensated congestive heart failure.
3. Be familiar with the currently used methods for screening for coronary artery disease, and their limitations. (e.g. Dipyridamole thallium scanning, Exercise testing, Dobutamine stress echo, ambulatory Holter monitoring)
4. Know which patients should undergo a preoperative test for coronary artery disease
5. Know how to interpret the results of thallium scans
6. Know what further evaluation a patient with a positive study should have.
7. Know which patients should have coronary angiography prior to vascular surgery.
8. Understand that the magnitude of the operation should be tailored to the severity of the patient's cardiac risk. Know when to employ an extra anatomic, or limited procedure instead of an intra-abdominal operation.
9. Understand when, during the course of a vascular operation and subsequent recovery, a patient is most likely to suffer a myocardial infarction

### IV. Treatment

1. Recognize that most patients with even severe CAD can survive a major vascular operation, but they should have close postoperative cardiology follow up and subsequent consideration for coronary revascularization for the best long term survival.
2. Know when CABG may be indicated to correct severe CAD prior to peripheral vascular surgery.
3. Understand the indications for a combined CABG and CEA or AAA operation.
4. Understand the reasons for controlling myocardial ischemia intraoperatively, and during recovery from a major vascular operation

5. Know how to detect and treat myocardial ischemia postoperatively
6. Know how to diagnose and treat common complications of myocardial infarction.

## Pulmonary Disease

### I. Introduction

1. Recognize that many of the same risk factors that accelerate the development of peripheral vascular disease, also cause the development of chronic obstructive pulmonary disease (COPD)
2. Understand that long operations, intra-abdominal and thoracic incisions, and poor left ventricular function increase the risk of pulmonary complications even in the absence of underlying COPD.
3. Understand that cardiac and other co-morbid conditions are more important in determining postoperative pulmonary complications than pre-existing pulmonary disease

### II. Diagnosis

1. Know the risk factors for pulmonary disease, including: history of tobacco use, chest wall deformities, industrial dust exposure, previous pulmonary resection, dyspnea on mild exertion, pulmonary hypertension, recurrent respiratory tract infections, bronchospasm, obesity, advanced age and hypercapnia or hypoxia at rest.
2. Understand the signs and symptoms of COPD.
3. Know what to look for in the physical examination of a patient with suspected pulmonary insufficiency
4. Understand that clinical assessment is at least as accurate as routine preoperative pulmonary function tests in predicting which patients will have a postoperative pulmonary complication.
5. Understand that the primary benefit of preoperative pulmonary function studies is to make the diagnosis of pulmonary disease and as an aid in choosing between treatment alternatives.
6. Understand that there is no pulmonary function test, or index that can accurately predict that a patient will need prolonged postoperative mechanical ventilation.
7. Understand that general anesthesia interferes with pulmonary gas exchange and pulmonary defense mechanisms, particularly the mucociliary transport mechanism.
8. Know how to interpret the results of pulmonary function tests, and know which patients might benefit from the perioperative use of bronchodilators, antibiotics, inhalers etc.
9. Know which patients might benefit from a preoperative pulmonary or anesthesia consultation to help with the operative and postoperative management of a patient with known pulmonary insufficiency

### III. Treatment

1. Understand how to reduce the pulmonary risk of a vascular operation by the choice of operation and anesthesia.
2. Understand which pulmonary conditions may benefit from the perioperative use of steroids, bronchodilators, antibiotics and inhalers
3. Understand the causes and treatment of the adult respiratory distress syndrome (ARDS)

## References

### Cardiac Disease

1. Mackey WC, O'Donnell TF, Callow AD. Cardiac risk in patients undergoing carotid endarterectomy: Impact on perioperative and long-term mortality, J Vasc Surg 11:226-34; 1990.
2. Perry MO, Calcagno D. Abdominal aortic aneurysm surgery: The basic evaluation of cardiac risk. Ann Surg 208:738-741;1988.
3. Cooperman M, Pflug B, Martin EW, Evans WE. Cardiovascular Risk Factors in patients with peripheral vascular disease. Surgery; 84:505-9;1978.
4. Hertzner NR, Beven EG, Young JR, et al. Coronary artery disease in peripheral vascular patients: A

- classification of 1000 coronary angiograms and results of surgical management. *Ann Surg* 199:223-33;1984.
5. Goldman L. Cardiac risks and complications of noncardiac surgery. *Ann Intern Med* 98:504-13;1983.
  6. Boucher CA, Brewster DC, Darling RC, Okada RD, Strauss HW, Pohost GM. Determination of Cardiac risk by dipyridamole thallium imaging before peripheral vascular surgery. *NEJM* 312:389-94; 1985.
  7. Eagle KA, Singer DE, Brewster DC, Darling RC, Mulley AG, Boucher CA. Dipyridamole thallium scanning in patients undergoing vascular surgery: Optimizing preoperative evaluation of cardiac risk. *JAMA* 257:2185-9;1987.
  8. Mangano DT, Goldman L. Preoperative assessment of patients with known or suspected coronary disease. *NEJM* 333:1750-56;1995.
  9. Lachapelle K, Graham AM, Symes JF. Does the clinical evaluation of the cardiac status predict outcome in patients with abdominal aortic aneurysms? *J Vasc Surg* 25:964-71;1992.
  10. Arous EJ, Baum PL, Cutler BS. The ischemic exercise test in patients with peripheral vascular disease. *Arch Surg* 119:780-3;1984.
  11. Poldermans D, Fioretti PM, Forster T, Thomson IR, et al. Dobutamine Stress Echocardiography for Assessment of peroperatrive cardiac risk in patients undergoing major vascular surgery. *Circulation* 87:1506-12;1993.
  12. Raby KE, Goldman L, Creager MA, Cooke JP, Hlatkey MA. The role of coronary angiography and coronary revascularization before noncardiac vascular surgery. *JAMA* 273:1919-25;1995.
  13. Seeger JM, Rosenthal GR, Self SB, Flynn TC, Limacher MC, Harward TRS. Does routine stress-thallium cardiac scanning reduce postoperative cardiac complications? *Ann Surg* 219:654-63;1994.
  14. Cronnenwett JL, Murphy TF, Selkenock GB, Whitehouse WM, Lindenauer SM, Graham LM, Quint LZE, Silver TM, Stanley JC. Actuarial analysis of variables associated with the rupture of small aortic aneurysms. *Surgery* 98:472-83;1985.
  15. Cutler BS, Hendel RC, Leppo JC. Dipyridamole thallium scintigraphy predicts perioperative and long-term survival after major vascular surgery. *J Vasc Surg* 15:972;1992.
  16. Massie MT, Rohrer MJ, Leppo JA, Cutler BS. Is coronary angiography necessary for vascular surgery patients with a positive dipyridamole thallium scan? *J Vasc Surg*. In press.
  17. Kazmers A. *Cardiac Risk Assessment Before Vascular surgery*. Futura Publishing Co. Armonk NT 1994.

### Pulmonary

1. Bartlett RH, Pulmonary Insufficiency. Chapter in Wilmore DW, Brennan MF, Harken AH, et all (eds): *Care of the Surgical Patient*, New York. Scientific American 1989.
2. Lawrence VA, Page CP, Harris GD: Preoperative spirometry before abdominal operations. A critical appraisal of its predictive value. *Arch Intern Med* 149:280;1989.
3. Gennaro MT, Preoperative Evaluation of Pulmonary Function. Validity, Indications and Benefits.. *Am Rev Resp Dis* 119:293-310;1970.
4. Arabian AA, Spagnolo SV, Prashant KR. Evaluation and Therapy of Pulmonary Problems in Surgical Patients. *Clinical Notes Resp Dis* 21:3-14;1982.
5. Jayr C, Matthay MA, Goldstone J, Gold WM, Wiener-Kronish JP. Preoperative and Intraoperative Factors Associated with Prolonged Mechanical Ventilation. A study in patients following major abdominal vascular surgery. *Chest* 103:1231-1236.
6. Williams-Russo P, Charson ME, MacKenzie CR, Gold JP, Shires TG. Predicting Postoperative Pulmonary Complications. Is it a real problem? *Arch Intern Med* 152:1209-1213;1992.
7. Spivack SD, Shinozaki T, Albertini JJ, Deane R. Preoperative Predication of Postoperative Respiratory Outcome. Coronary artery bypass grafting. *Chest* 109:1222-30;1996.
8. Zibrak JD, O'Donnell CR, Marton K. Indications for Pulmonary Function Testing. *Ann Intern Med* 112:763-771;1990.
9. Zibrak JD, O'Donnell CR, Marton, KI et al. Preoperative Pulmonary Function Testing. A Position Paper of

the American College of Physicians. *Ann Intern Med* 112:793-794;1990.

## 19. Coagulation Disorders

Richard M. Green, M.D., Donald Silver, M.D.

### I. Heparin

1. To understand the role of antithrombin III and the dual action of heparin on thrombin (factor II) and factor Xa (IX a and XI a also).
2. To be familiar with its half-life, routes of administration and its uses both in terms of prevention of thrombosis and in treatment for thrombotic conditions.
3. To be familiar with the hematologic and nonhematologic complications.
4. To understand the intraoperative use including monitoring techniques and reversal.
5. To understand the mechanism of action and complications of protamine sulfate.

### II. Low Molecular Weight Heparin (LMWH)

1. To understand the rationale for its development and its advantages over unfractionated heparin.
2. To understand the different mechanism of action as compared to unfractionated heparin.
3. To understand why it can be used without monitoring.
4. To understand why it is less hemorrhagic than unfractionated heparin.
5. To understand the clinical applications particularly in the patient with heparin induced thrombocytopenia and prophylaxis for venous thrombosis.
6. To understand the cost benefits of out patient treatment of venous thrombosis.

### III. Heparin-induced Thrombocytopenia (HIT)

1. To understand the incidence of the syndrome in patients receiving heparin, the incidence of thrombotic complications and the mortality rate.
2. To understand the risk factors associated with its development.
3. To understand the differences between Type I and Type II HIT.
4. To understand the diagnostic criteria necessary to make the diagnosis.
5. To understand the pathophysiology of antibody formation.
6. To understand the principles of management.
7. To understand the limitations of the various diagnostic tests including platelet aggregation studies, the serotonin release assay and the PF4/heparin ELISA assay.
8. To understand when further anticoagulation is indicated and what agents are available and under development.

### IV. Coumadin

1. To understand the mechanism of action including the roles of proteins C and S.
2. To understand why heparin should be given for the first 3-4 days of coumadin treatment.
3. To understand the medical conditions, foods and common drugs that affect coumadin's anticoagulant activity.
4. To understand how to minimize the complications of coumadin therapy.
5. To understand the American College of Chest Physicians recommendations of appropriate INR levels. This should include a working knowledge of the conditions which require higher levels.
6. To understand how and when to reverse anticoagulation in patients with and without hemorrhage.
7. To understand how to manage patients requiring surgery.

### V. Antiplatelet therapy

1. To understand the role of platelets in primary and secondary hemostasis.
2. To understand the role of platelets in pathologic thrombosis.

3. To understand the structure of the platelet and the function of each zone.
4. To understand the sequence of platelet activation including a knowledge of the glycoprotein complexes and the role of von Willebrand's factor.
5. To understand the various platelet agonists and antagonists and their relative strengths.
6. To have a working knowledge of antiplatelet agents currently available and their mechanisms of action. This includes an understanding of the relative strengths of the antagonists: aspirin, ticlopidine, dextran, and dipyridamole.
7. To be familiar with the mechanism of action of some antiplatelet agents under investigation including von Willebrand factor monoclonal antibody, arabinic acid, glycoprotein IIb/IIIa receptor antagonists, thromboxane/endoperoxide receptor inhibitors, prostaglandin E<sub>1</sub> prostacyclin, proteolytically inactive mutant thrombins, and trapidil.

#### VI. The Detection of Abnormal Bleeding

1. To understand the relevant historical information in patients with a bleeding disorder.
2. To understand the coagulation studies that should be done routinely and those that should be done when a bleeding disorder is suspected.
3. To understand the importance of spontaneous ecchymosis and petechiae.
4. To understand the specific clinical presentation, genetic transmission and factor deficiency in hemophilia A, hemophilia B and von Willebrand's disease.
5. To understand the purpose of the bleeding time, the significance and common causes of an abnormal test.
6. To understand how to evaluate the intrinsic coagulation cascade and what drugs and factor deficiencies affect it.
7. To understand the significance of circulating inhibitors such as the lupus anticoagulant.
8. To understand how to evaluate the extrinsic coagulation cascade and what drugs or factor deficiencies affect it.
9. To have a working knowledge of the work-up and management of perioperative bleeding.

#### VII. The Use of Blood Products for Surgical Bleeding

1. To understand the risks of blood products and why transfusion practices have changed.
2. To understand the indications for red cell transfusions including a knowledge of the myocardial work requirements at hemoglobin levels of <7g/dL, between 8 and 10 g/dL and >10g/dL.
3. To understand the risks of and indications for administration of fresh-frozen plasma and cryoprecipitate.
4. To understand the indications for platelet transfusions in asymptomatic patients, patients who require a surgical procedure, and patients who have spontaneous bleeding.

#### VIII. Use of Desmopressin (DDAVP) in Vascular Surgery

1. To understand the properties, mechanism of action, and indications for its use.
2. To understand the phenomenon of tachyphylaxis including why it occurs and its significance.

#### IX. Hypercoagulability Syndromes

1. To understand the significant history, work-up and treatment for antithrombin III deficiency, protein C and S deficiency, factor V (Leiden) mutation [activated protein C resistance].
2. To understand the role of pregnancy and oral contraceptives on thrombosis.
3. To understand the need for thromboembolism prophylaxis in the various acute phase reactions such as trauma or operation.
4. To understand the significance of antiphospholipid antibodies including the types of patients at risk and the management implications.
5. To understand the role of screening in routine patients and high risk patients.

6. To understand the effects of coumadin, heparin and antiplatelet agents on lab measurements for hypercoagulability.
7. To understand the differential diagnosis and management of intraoperative clotting including the management of intimal injury, heparin induced thrombosis or antithrombin III deficiency.

#### X. Ancrod

1. To understand the derivation, mechanism of action, and uses.
2. To understand its effect on blood viscosity and its possible benefit in patients with arterial ischemia.
3. To understand the differences between the fibrinolytic activity of ancrod as compared to urokinase.
4. To understand the risks of too rapid defibrination.
5. To understand the risks of a lack of fibrin on wound healing.
6. To understand the management of ancrod induced bleeding complications.

**20. Diagnosis and Management of Miscellaneous Vasculogenic Problems**

Blair A. Keagy, M.D., Mark A. Farber, M.D., Sean D. O'Donnell, M.D., John J. Ricotta, M.D.

I. Anatomy and Pathophysiology

A. Raynaud's Syndrome

1. To understand the epidemiology and pathophysiology surrounding Raynaud's Syndrome.
2. To define the epidemiologic parameters involved in Raynaud's Disease.
3. To define the physiologic mechanism occurring in Raynaud's Phenomenon.
4. To define the criteria for obstructive Raynaud's Syndrome.
5. To define the role of adrenergic receptors in the cause of Raynauds.

B. Neurogenic Thoracic Outlet Syndrome

1. To understand the anatomy of the thoracic outlet and the anatomic predisposition to developing TOS, including osseous abnormalities, and soft tissue abnormalities.
2. To understand the association of trauma, both direct and indirect, with the development of TOS.
3. To define the histological changes described in the scalene muscles of patients with TOS.

C. Causalgia/Reflex Sympathetic Dystrophy

1. To understand the pathogenesis of causalgia including that of artificial synapses, and the cycle of reflexes.
2. To define the clinical stages of Drucker, along with their characteristics and symptoms.

D. Vasculogenic Impotence

1. To describe to physiology involving erection including the blood supply, and innervation.
2. To define the differences associated with organic, psychogenic, neurogenic, and vasculogenic impotence.

E. Pediatric Vascular Disorders

1. To define and recognize the various congenital vascular lesions in children.
2. To recognize the problems associated with hemangiomas.
3. To understand renovascular hypertension in the pediatric population.
4. To understand the pathophysiology of renal vein thrombosis.

II. Diagnostic Evaluation

A. Raynaud's Syndrome

1. To understand the clinical presentation of patients with Raynaud's Syndrome. and their presenting symptoms.
2. To recognize the associated diseases.
3. To define the appropriate use of laboratory testing in the diagnosis of Raynauds, including the occlusive digital hypothermic challenge test, angiography and plethysmography.

B. Neurogenic Thoracic Outlet Syndrome

1. To define the demographic aspects of patients presenting with TOS.
2. To recognize the symptoms associated with the disease, including pain, parasthesias, and associated symptoms.
3. To recognize the musculoskeletal disorders that mimic TOS.
4. The utilization of diagnostic tests including the Tinel and Phalen test, Adson test, and the arm stress test, and recognize the physical findings suggestive of TOS along with their sensitivity and shortcomings.
5. To understand the role of ancillary diagnostic tests in the work-up of TOS including, but not confined to, chest radiographs.

6. To recognize the need for a complete neurologic examination in these patients.
7. To define the role of electrophysiology studies in the evaluation including ulnar nerve conduction velocities, electromyography, and somatosensory evoked potentials.

#### C. Causalgia/Reflex Sympathetic Dystrophy

1. To understand the presenting symptoms and differential diagnosis of causalgia.

#### D. Vasculogenic Impotence

1. To understand the role of non-invasive vascular testing.
2. To understand the role of indirect neurologic testing in impotence.
3. To recognize the usefulness of intracavernous papaverine injection and angiography in the diagnosis of impotence.

#### E. Pediatric Vascular Disorders

1. To recognize the clinical presentation of renal vein thrombosis in children and its diagnostic evaluation.

### III. Treatment

#### A. Raynaud's Syndrome

1. To recognize the medications that should be avoided in these patients.
2. To define the use of sympatholytic agents, and their replacement by calcium channel blockers.
3. To recognize the role of new therapies for treatment.

#### B. Neurogenic Thoracic Outlet Syndrome

1. To identify the role of conservative treatment for TOS.
2. To define the operative treatment of TOS including the choices for operative exposure, role of scalenectomy, concept of total decompression, and rationale for sparing the first rib.
3. To recognize the complications associated with the procedure including nerve, vascular, and lymphatic injuries.

#### C. Causalgia/Reflex Sympathetic Dystrophy

1. To define the timing of operative therapy for RSD, along with its results.
2. To identify the complications surrounding the procedure and the disease.

#### D. Vasculogenic Impotence

1. To understand the means of prevention of impotence during surgical procedures of the aorta and the results of appropriate revascularization.
2. To define the risk of impotence with associated vascular procedures.
3. To define the role of revascularization of the penis.

#### E. Pediatric Vascular Disorders

1. To define the treatment strategies for renal vein thrombosis.
2. To understand the treatment options in children with congenital vascular lesions.

### References

1. Coffman JD, Cohen AS,: Total and capillary fingertip blood flow in Raynaud's phenomenon. N Engl J Med 285:259,1971.
2. Porter JM, Rivers SP, Anderson CJ, et al: Evaluation and Management of patients with Raynaud's

Syndrome. *Am J Surg* 142:183, 1981.

3. Zweifler AJ, Trinkus P: Occlusive digital artery disease in patients with Raynaud's phenomenon. *Am J Med* 77:995, 1984.

4. Downs AR, Gaskell P, Morrow I, et al: Assessment of arterial obstruction in vessels supplying the fingers by measurement of local blood pressures and the skin temperature response test - Correlation with angiographic evidence. *Surgery* 77:530, 1975.

5. Stoney RJ, Cheng SWK: Neurogenic Thoracic Outlet Syndrome, in Rutherford RB (ed): *Vascular Surgery*. Philadelphia, PA, Saunders, 1995, pp 976-992.

6. Sanders RJ, Pearce WH: The treatment of thoracic outlet syndrome; A comparison of different operations. *J Vasc Surg* 10:626, 1989.

7. Rutherford R: Causalgia and Post-Traumatic Pain Syndromes, in Rutherford RB (ed): *Vascular Surgery*. Philadelphia, PA, Saunders, 1995, pp736-740.

8. Mockus MB, Rutherford RB, Rosales C, et al: Sympathectomy for causalgia: patient selection and long-term results. *Arch Surg* 122:668, 1987.

9. Kempczinski RF: Role of the vascular diagnostic laboratory in the evaluation of male impotence. *Am J Surg* 138:278, 1979.

10. DePalma RG: Impotence in vascular disease: Relationship to vascular surgery. *Br J Surg* 69:514, 1982.

11. Flanigan DP, Schuler JJ, Keifer T, et al: Elimination of iatrogenic impotence and improvement of sexual function after aortoiliac revascularization. *Arch Surg* 117:544, 1982.

12. Michal V, Kramar R, Hejhal L: Revascularization procedure of the cavernous bodies. In Zоргomotti AW, Rossi G (eds): *Vasculogenic Impotence: Proceedings of the First International Conference on Corpus Cavernosum Revascularization*. Springfield, IL, Charles C Thomas, 1980.

13. Mulliken JB, Glowacki J. Hemangiomas and vascular malformations in infants and children: A classification based on endothelial characteristics. *Plast Reconstr Surg* 1982; 69:412-422.

14. Ricci MA, Lloyd DA. Renal venous thrombosis in infants and children. *Arch Surg* 1990; 125:1195-1199.

15. Summer DS, Strandness DE Jr: An abnormal finger pulse associated with cold sensitivity. *Ann Surg* 175:294:1972.

16. Gates KN, Tyburczy JA, Zupan T, et al: The non-invasive quantification of digital vasospasm. *Bruit* 8:34, 1984.

17. Clifford PC, Martin MFR, Sheddon EJ, et al: Treatment of vasospastic disease with prostaglandin E1. *Br Med J* 2:1031, 1980.

## 21. **Non-Atherosclerotic Vascular Diseases**

William L. Smead, M.D., R. Eugene Zierler, M.D.

### I. Immune Arteritis

1. To understand the basic pathologic mechanisms of vascular injury in the immune arteritis syndromes.
2. To define a classification system for the vasculitides on the basis of clinical findings, pathology, and prognosis in a way that assists in the diagnosis and management of these patients, recognizing the considerable overlap that exists among these diseases. This classification system would include the systemic necrotizing vasculitides, the hypersensitivity vasculitides, giant cell arteritis, and a diverse miscellaneous group.
3. To recognize the clinical problems which should alert the physician to consider a systemic vasculitis, particularly ischemic symptoms involving multiple organ systems in patients under 55 years of age, involving organs and limbs in distributions not typical for atherosclerosis, and occurring at an unusually accelerated pace.
4. To understand the basic clinical laboratory tests useful in the diagnosis and management of vasculitis. Diagnostic tests range from routine evaluations to more specific tests for defining the immunophysiology. Management requires testing to define the current inflammatory status as well as specific measurements of organ function.
5. To understand the role of arteriography and the characteristic findings in the arteritis syndromes of surgical significance.
6. To recognize the role of tissue biopsy in establishing a firm diagnosis.
7. To recognize the clinical presentation of polyarteritis nodosa, the laboratory and pathologic features of the disease which establish the diagnosis, and the complications of the disease with surgical significance.
8. To be familiar with the small vessel complications of hypersensitivity angiitis, a large category of vasculitides with a wide variety of etiologies including infection, drug and chemical allergies, connective tissue diseases, neoplasm, Henoch-Schönlein purpura, serum sickness, cryoglobulinemia, and a large miscellaneous category represented by chronic active hepatitis, primary biliary cirrhosis, inflammatory bowel disease, and intestinal bypass surgery. To understand the medical and surgical management of ischemic complications of these disorders.
9. To recognize the giant cell arteritis group of diseases which includes temporal arteritis and Takayasu-Onishi disease. To understand the distinctive arteriographic patterns of these disorders and the medical and surgical treatment strategies.
10. To be familiar with the miscellaneous vasculitis syndromes of surgical significance, including Kawasaki's syndrome, Behcet's disease, Cogan's syndrome, and Buerger's disease.

### II. Fibromuscular Dysplasia

1. To understand the pathologic classification of fibromuscular dysplasia: intimal fibroplasia, medial fibroplasia, medial hyperplasia, and perimedial dysplasia.
2. To recognize the vascular beds most frequently affected by this disorder (renal, cerebrovascular, mesenteric, and aortoiliac arteries) and the symptoms with which patients most frequently present.
3. To recognize the arteriographic patterns distinguishing each of the types of fibromuscular disease from each other and atherosclerosis.
4. To understand the natural history of fibromuscular disease in its various locations and its impact on clinical decision making.
5. To understand the various treatment options available including endovascular techniques and surgical bypass.

### III. Adventitial Cystic Disease

1. To understand this rare condition producing arterial stenosis or occlusion in young patients, its clinical presentation, arteriographic features, operative findings, and management options.

#### IV. Popliteal Intraplant Syndromes

1. To understand the clinical presentation of this congenital anomaly predominantly affecting young men, its characteristic noninvasive vascular laboratory and arteriographic findings (provocative testing), and the available treatment alternatives.
2. To be familiar with the various anatomic variants which produce the abnormal relationship between the popliteal artery and the medial head of the gastrocnemius muscle.
3. To recognize the characteristic findings suggesting the adductor canal syndrome in which the junction of the superficial femoral and popliteal arteries is compressed by the tendinous insertion of the adductor magnus muscle at Hunter's canal.

#### V. Compartment Syndromes

1. To understand the multiple etiologies of compartment syndromes which have in common the production of sufficient compartmental pressure to compromise blood flow to the tissues within it, conditions which decrease compartmental volume or increase compartmental content or provide excessive external pressure.
2. To recognize those clinical situations in which compartment syndrome is more likely to develop complicating vascular injury or disease: prolonged ischemia, coexistent shock, preoperative neurologic deficits, pre- or intraoperative edema, combined arterial and venous injury, or concomitant crush injury.
3. To recognize the symptoms and signs of elevated compartment pressure and the tests available to confirm the diagnosis.
4. To understand the indications for fasciotomy and the surgical techniques available.
5. To understand the medical management of established rhabdomyolysis.

#### VI. Congenital Arterial Conditions

1. To be familiar with the various types of abdominal coarctations and their clinical presentations and natural history.
2. To understand the role of arteriography in the diagnosis of the problem and the planning of surgical treatment of abdominal coarctation.
3. To be familiar with the surgical options for repair and renal revascularization in patients with abdominal coarctation.
4. To recognize the arteriographic findings in patients with a persistent sciatic artery and the potential surgical implications.

#### VII. Diseases of the Arterial Media

1. To understand the pathologic changes of cystic medial necrosis which result in the clinical problems of aortic dissection, spontaneous rupture, and aneurysm formation.
2. To recognize the classic abnormalities associated with Marfan's syndrome and the typical cardiovascular complications.
3. To understand the natural history of Marfan's syndrome and the management options available to treat these cardiovascular problems.
4. To recognize the characteristic abnormalities in patients with Ehlers-Danlos syndrome and the issues of surgical significance including aneurysm formation, dissection, and spontaneous rupture.
5. To be familiar with the vascular changes in patients with pseudoxanthoma elasticum, arterial stenosis/occlusion and hypertension.
6. To recognize the changes associated with arteria magna syndrome and the role of arteriography in diagnosis, treatment, and patient follow-up.

### VIII. Errors in Homocysteine Metabolism

1. To understand the inborn error of metabolism that produces homocysteinuria and the associated multiple abnormalities including mental retardation, lens ectopia, rapidly progressive premature atherosclerosis, and thromboembolic disorders.
2. To be familiar with the heterozygous trait which results in homocysteinemia and premature atherosclerosis, potentially ameliorated by treatment with folic acid, pyridoxine, and vitamin B<sub>12</sub>.

### IX. Hyperviscosity Syndromes

1. To understand the myeloproliferative disorders and serum protein abnormalities that result in arterial or venous thromboembolism.

### X. Arterial Infections

1. To recognize the symptoms and signs of arterial infections and the most common responsible pathogens.
2. To understand the etiologies of arterial infection including bacterial endocarditis, mycotic or infected aneurysms, drug abuse, iatrogenic contamination, and contiguity to adjacent infection.
3. To recognize the most effective techniques for obtaining positive cultures on which to base antibiotic treatment in patients with arterial infections.
4. To be familiar with the principles and treatment strategies for the management of arterial infection.

### XI. Vasospastic Disorders

1. To understand the classification of cold sensitivity of the Raynaud type (Raynaud's disease and Raynaud's phenomenon).
2. To recognize the common clinical presentations of vasospasm due to cold sensitivity.
3. To be familiar with the noninvasive diagnostic evaluation of digital ischemia and vasospasm.
4. To understand the features of uncommon vasospastic disorders, including livedo reticularis, acrocyanosis, and erythromelalgia.
5. To be familiar with the various treatment approaches to primary and secondary vasospasm.

### References

1. Porter JM, Taylor LM, Harris EJ Jr. Nonatherosclerotic vascular disease. In Moore WS, editor. Vascular Surgery - A Comprehensive Review, Fourth Edition. Philadelphia: W.B. Saunders Company, 1993: 108-145.
2. McKusick VA, Harris WS, Ottesen OE et al. Buerger's disease: A distinct clinical and pathologic entity. JAMA 1962; 181:93.
3. Ninet JP, Bachet P, Dumontet CM, et al. Subclavian and axillary involvement in temporal arteritis and polymyalgia rheumatica. Am J Med 1990; 88:13.
4. Parums DV. The arteritides. Histopathology 1994; 25:1.
5. Tordoir JH, Haeck LB, Winterkamp H, et al. Multifinger photoplethysmography and digital blood pressure measurement in patients with Raynaud's phenomenon of the hand. J Vasc Surg 1986; 3:456.
6. Russo CP, Smoker WRK. Nonatheromatous carotid artery disease. Neuroimaging Clin N Am 1996; 6:811.
7. Mills JL, Porter JM. Buerger's disease: A review and update. Semin Vasc Surg 1993; 6:14.
8. Shionoya S. Buerger's disease: Diagnosis and management. Cardiovasc Surg 1993; 1:207.
9. Somer T. Thrombo-embolic and vascular complications in vasculitis syndromes. Eur Heart J 1993; 14(Suppl K):24.
10. Hayreh SS, Podhajsky PA, Raman R, et al. Giant cell arteritis: Validity and reliability of various diagnostic criteria. Am J Ophthalmol 1997; 123:285.

11. Gabriel SE, O'Fallon WM, Achkar AA, et al. The use of clinical characteristics to predict the results of temporal artery biopsy among patients with suspected giant cell arteritis. *J Rheumatol* 1995; 22:93.
12. Nordborg E, Nordborg C, Malvall BE, et al. Giant cell arteritis. *Rheum Dis Clin N Am* 1995; 21:1013.
13. Bengtsson BA, Andersson R. Giant cell and Takayasu's arteritis. *Curr Opin Rheumatol* 1991; 3:15.
14. Kerr GS. Takayasu's arteritis. *Rheum Dis Clin N Am* 1995; 21:1041.
15. Cleophas TJ, Niemeyer MG. Raynaud's syndrome: An enigma after 130 years. *Angiology* 1993; 44:196.
16. Smith CR, Rodeheffer RJ. Raynaud's phenomenon: Pathophysiologic features and treatment with calcium-channel blockers. *Am J Cardiol* 1985; 55:154B.
17. Collins PS, McDonald PT, Lim RC. Popliteal artery entrapment: An evolving syndrome. *J Vasc Surg* 1989; 10: 484.
18. Rizzo RJ, Flinn WR, Yao JS, et al. Computed tomography for evaluation of arterial disease in the popliteal fossa. *J Vasc Surg* 1990; 11: 112.
19. Schutze WP, Garrett WV, Smith BL. Persistent sciatic artery: Collective review and management. *Ann Vasc Surg* 1993; 7: 303.
20. Wolf YG, Gibbs BF, Guzzetta, Bernstein EF. Surgical treatment of aneurysm of the persistent sciatic artery. *J Vasc Surg* 1993; 17: 218.
21. Flanigan DP, Burnham SJ, Goodreau JJ, et al. Summary of cases of adventitial cystic disease of the popliteal artery. *Ann Surg* 1979; 189: 165.
22. Masser PA, Taylor LM Jr, Porter JM. Importance of elevated plasma homocysteine levels as a risk factor for atherosclerosis. *Ann Thorac Surg* 1994; 58: 1240.
23. Lüscher TF, Lie JT, Stanson AW, et al. Arterial fibromuscular dysplasia. *Mayo Clin Proc* 1987; 62: 931.
24. Perry MO. Compartment syndromes and reperfusion injury. *Surg Clin N Am* 1988; 68: 853.

## 22. **Arteriovenous Malformations and Arteriovenous Fistulae**

Michael A. Golden, M.D., James C. Stanley, M.D., Thomas C. Naslund, M.D.

### I. Anatomy and Pathophysiology

1. To understand the pathophysiology of arteriovenous malformations (AVM) and arteriovenous fistulae (AVF). This includes the rare forms (congenital and acquired) and the more common forms (traumatic and iatrogenic) of arteriovenous communications.
2. To define the influences of age, location, presenting symptoms and past medical, surgical and traumatic history on the etiology of arteriovenous communications, and to recognize the importance of syndromes with AVM.
3. To understand the common risk factors for the development of acquired arteriovenous communications, and how to anticipate and minimize the risks.
4. To understand the clinical settings associated with congenital AVM and to recognize them without delay.
5. To understand the early and the late important hemodynamic properties and effects of arteriovenous communications, and the effects of these changes on perfusion.
6. To understand the adaptive responses to the abnormal hemodynamics associated with arteriovenous communications.
7. To understand the natural history of arteriovenous communications as a function of the type of communication, (etiology, location, size, comorbidity and complications).
8. To understand the principles for the creation of arteriovenous communications for therapeutic indications, such as dialysis access, and distal extremity bypass grafts and venous bypass grafts.
9. To understand the technical considerations for the creation of arteriovenous communications for therapeutic indications, such as dialysis access, and distal extremity bypass grafts and venous bypass grafts.
10. To understand the complications and problems with therapeutic arteriovenous communications.

### II. Diagnostic Evaluation

1. To understand the patterns of presentation of patients with arteriovenous malformations (AVM) and arteriovenous fistulae (AVF). This includes the rare forms (congenital and acquired) and the more common forms (traumatic and iatrogenic) of arteriovenous communications.
2. To understand the role of history and physical examination in the diagnosis of arteriovenous communications.
3. To define appropriate, cost effective diagnostic testing for arteriovenous communications.
4. To understand the role of the vascular diagnostic laboratory for the diagnostic evaluation of arteriovenous communications.
5. To understand the role of magnetic resonance imaging and magnetic resonance angiography for the diagnostic evaluation of arteriovenous communications.
6. To understand the role of contrast angiography for the diagnostic evaluation of arteriovenous communications.
7. To understand the role of diagnostic studies for the selection of the patient and site, and the preparation for the creation of a therapeutic arteriovenous communication.
8. To understand the diagnostic evaluation of the complications and problems with therapeutic arteriovenous communications.

### III. Treatment

1. To understand the role of conservative management for arteriovenous communications.
2. To understand the role of catheter based intervention in the treatment of arteriovenous communications.
3. To understand the role of open surgery in the treatment of arteriovenous communications.
4. To understand the interactions of the treatments and the expected impact of combinations of treatments of

arteriovenous communications.

5. To understand the principles for the creation of arteriovenous communications for therapeutic indications, such as dialysis access, and distal extremity bypass grafts and venous bypass grafts.
6. To understand the technical considerations for creation of arteriovenous communications, for therapeutic indications, such as dialysis access, and distal extremity bypass grafts and venous bypass grafts.
7. To understand the complications and problems with therapeutic arteriovenous communications.
8. To understand the advantages and disadvantages of therapeutic AVF.

### References

1. Congenital vascular defects and hemangiomas, Rutherford RB, Loose DA (eds): Seminars in Vascular Surgery, Philadelphia, WB Sanders, 1993, Vol 6, No 4.
2. Thomas S. Riles, M.D.: Overview. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1163-1165.
3. David S. Sumner, M.D.: Hemodynamics and Pathophysiology of Arteriovenous Fistulae. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1166-1191.
4. Robert B. Rutherford, M.D. and David S. Sumner, M.D.: Diagnostic Evaluation of Arteriovenous Fistulae. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1192-1206.
5. William H. Baker, M.D.: Arteriovenous Fistulae of the Aorta and its Major Branches. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1207-1210.
6. Thomas S. Riles, M.D., Robert J. Rosen, M.D. and Alejandro Berenstein, M.D.: Peripheral Arteriovenous Fistulae. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1211-1217.
7. Robert J. Rosen, M.D., Thomas S. Riles, M.D. and Alejandro Berenstein, M.D.: Congenital Vascular Malformations. Arteriovenous communications and congenital vascular malformations. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1218-1232.
8. Timothy P. Connall, M.D. and Samuel E. Wilson, M.D.: Vascular Access for Hemodialysis. Angioaccess. In Rutherford RB (ed): Vascular Surgery. 4th ed Vol 2, Philadelphia, WB Sanders, 1995 pp 1233-1244.
9. John D. Bennett M.D. and Saadoon Kadir, M.D.: Renal Arteriovenous Malformation and Arteriovenous Fistula. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 830-833.
10. Robert B. Rutherford, M.D.: Classification of Peripheral Congenital Vascular Malformations. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 834-838.
11. William H. Pearce, M.D. and Robert L. Vogelzang, M.D.: Evaluation of Congenital Vascular Malformations of the Extremities by Nonangiographic Methods. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 839-840.
12. S. Martin Lindenauer, M.D.: Acquired Arteriovenous Fistula. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 841-845.
13. Steven R. Buchman, M.D. and David J. Smith, Jr., M.D.: Congenital Vascular Lesions in Infancy and Childhood. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 846-849.
14. Thomas S. Riles, M.D. and Mark A. Adelman, M.D.: Management of Congenital Arteriovenous Fistulas and Malformations in Adults. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 850-852.
15. Jeffrey L. Buehrer, M. D. and Blair A. Keagy, M.D.: Direct Arteriovenous Anastomosis for Angioaccess.

In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 857-859.

16. Richard W. Dow, M.D. and Sheldon A. Schwartz, M.D.: Bridge Grafts for Angioaccess. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 860-864.

17. Armen Vartany, M.D., Martin J. Winkler, M.D., and Samuel E. Wilson, M.D.: Surveillance of Angioaccess Graft Function. In Current Therapy in Vascular Surgery. Ernst CB, Stanley JC (eds): 3rd ed, St. Louis, MI, Mosby, 1995 pp 865-867.

18. B. O. Anderson, M.D., R. B. Rutherford, M.D. and D.E. Szilagy, M.D.: Congenital vascular malformations of the extremities. In Vascular Surgery: A Comprehensive Review, Moore WS (ed): Philadelphia, WB Saunders, 1991, 3rd ed, pp 131-140.

19. R. S. Bennion, M.D., and S.E. Wilson, M.D.: Hemodialysis and Vascular Access. In Vascular Surgery: A Comprehensive Review, Moore WS (ed): Philadelphia, W.B. Sanders, 1991, 3rd ed, pp 537-559.

## 23. Vascular Access

Mitchell H. Goldman, M.D., Enrico Ascer, M.D., Gary Peterson, M.D.

### I. Anatomy and Pathophysiology

1. To know that arterial and venous anatomy involved in the commonly placed grafts and sited for hemodialysis in the upper and lower extremities; know the options for unusual grafts sites when extremities are not available.
2. To know the local and systemic, anatomic effects of creating an arteriovenous fistula for the purpose of hemodialysis.
3. To know the anatomic landmarks for the various routes of access to the circulation for the use of chemotherapy, chronic infusion, obtaining blood samples, and physiologic monitoring.
4. To know the hemodynamic and physiologic effects of creating an arteriovenous fistula; understand the effects of large and small fistulae on the adjacent arteries and veins and on the body as a whole.
5. To know the anatomic and physiologic etiologies for arterial steal, decreased extremity flow and venous hypertension in AV fistulas created for hemodialysis.

### II. Diagnostic Evaluation

1. To know the physical exam and diagnostic tests used in selecting a site for a vascular access including Allen's test, use of duplex screening of veins, and stereography.
2. To know the diagnostic tests used in evaluating an arteriovenous access with high resistance, poor pressure, thrombosis, and infection.
3. To know the complications of obtaining access to the central circulation and the diagnostic examinations and tests used to diagnose pneumothorax, misplaced line, pseudoaneurysm, venous thrombosis, and hemorrhage.
4. To know the use of duplex scanning in the evaluation of AV accesses.

### III. Treatment

1. To know the uses and benefits of using autologous or synthetic grafts for the purpose of hemodialysis including the locations, timing of placement, maturation of and longevity of the various access routes and grafts.
2. To know the treatment of complications of arteriovenous fistulas for hemodialysis including infection, steal syndrome, aneurysms, venous hypertension, thrombosis, stenosis, and the failing graft.
3. To know the use of revision, patching, extending, banding, angioplasty and stenting as methods of prolonging AV access.
4. To know the advantages, techniques and commensurate applications of each route of access to the circulation for the use of administering chemotherapy, chronic infusions, obtaining blood samples and hemodynamic monitoring.
5. To know the complications of the above routes and their treatment.
6. To know the catheter types, their advantages, available for gaining access to the circulation.
7. To know the long term outcome and patencies of the various access types.

### References

1. Tordoir JH, DeBruin HG et al. Duplex ultrasound scanning in the assessment of arteriovenous fistulas created for hemodialysis access: comparison with digital subtraction angiography. *J Vasc Surg* 1989; 10 (2): 122-128.
2. Pagnon D, Green MA et al. Surveillance policy for early detection of failing arteriovenous fistulae for hemodialysis. *Nephrol Dial Transplant* 1994; 9: 277-279.
3. Rivers SP, Scher LA, Veith FJ. Correction of steal syndrome secondary to hemodialysis access fistulas: a

- simplified quantitative technique. *Surg* 1992; 112: 593-597.
4. Ballard JL, Bunt TJ, Malone JM. Major complications of angioaccess surgery. *Am J Surg* 1992; 164: 229-232.
  5. Chazan JA, London MR, Pono LM. Long-term survival of vascular access in a large chronic hemodialysis population. *Nephron* 1995; 69: 228-233.
  6. Feldman HI, Held PJ et al. Hemodialysis vascular access morbidity in the United States. *Kidney International* 1993; 43: 1091-1096.
  7. Mansfield PF, Holn DC, Fornage BD et al. Complications and failures of subclavian vein catheterization. *NEJM* 1994; 331: 1735-1738.
  8. Ramee SR. The role of percutaneous intervention in treating hemodialysis insufficiency. In Henry ML, Ferguson RM, editors. *Vascular Access for Hemodialysis-IV*. W. L. Gore & Associates, Inc., Precept Press 1995; 83- .
  9. Vorwerk D, Gunther RW et al. Follow-up results after stent placement in failing arteriovenous shunts: a three-year experience. *Cardiovasc Intervent Radiol* 1991; 14: 285-289.
  10. Turmel-Rodrigues L, Pengloan J et al. Insufficient dialysis shunts: improved long-term patency rates with close hemodynamic monitoring, repeated percutaneous balloon angioplasty, and stent placement. *Radiol* 1993; 187: 273-278.
  11. McDowell DE, Moss AH et al. Percutaneously placed dual-lumen silicone catheters for long-term hemodialysis. *Am Surg* 1993; 59: 569-573.
  12. Anderson CB, Allen BT, Sicard GA. Physiology and Hemodynamics of Vascular Access. In Sommer BG, Henry ML, editors. *Vascular Access for Hemodialysis*. W.L. Gore & Associates, Inc. Pluribus Press, Inc. 1989; 17-31.

## 24. Sympathectomy

Thomas S. Riles, M.D.

### I. Anatomy and Physiology

1. To understand the basic anatomy of the autonomic nervous system including the course of sympathetic fibers through the spinal cord, the location of the sympathetic ganglia and the course of the post synaptic fibers.
2. To understand the relationship between the sympathetic fibers and the abdominal aorta and iliac vessels.
3. To understand the functions of the sympathetic nervous system and the pathologic conditions resulting from abnormal sympathetic activity.
4. To understand the potential beneficial effects of sympathetic ablation and possible adverse side effects.

### II. Diagnostic Tests to Evaluate Sympathetic Function

1. To understand the basis of various tests to assess sympathetic activity.
2. To be aware of the limitations of the diagnostic tests used to assess sympathetic activity.

### III. Clinical Uses of Sympathectomy

1. To understand the historic and current role of sympathectomy for arterial occlusive disease.
2. To understand the probable outcome when sympathectomy is used for ischemic ulcers, gangrene, rest pain, and the differences in clinical response for diabetes and non-diabetes.
3. To be aware of the role of sympathectomy for Buerger's disease, embolic disease, Raynaud's phenomenon, causalgia and post traumatic rest pain, and hyperhidrosis.

### IV. Surgical Technique

1. To be aware of the technique for surgical ablation of the lumbar sympathetic chain as well as the technique for chemical ablation.
2. To be aware of the surgical technique for thoracodorsal sympathectomy.
3. To understand the potential complications from lumbar and thoracoabdominal sympathectomies and how to reduce the risk of complication.

### References

1. Cronenwett JL, Lundenou SM. Hemodynamic effect of sympathectomy in the ischemic canine hind limbs. *Surg* 1980; 87:417.
2. Sumner DS. Evaluation of acute and chronic ischemia of the upper extremity. Chapter 65 in *Vascular Surgery* 4th Ed (ed by Rutherford) WB Saunders, Co., Philadelphia, 1995; 924-25.
3. Rutherford RB. Valenta: Extremity blood flow and distribution. The effects of arterial occlusion, sympathectomy and exercise. *Surg* 1971; 69:332.
4. Rutherford RB, Shannon FL. Lumbar Sympathectomy: Indications and Techniques, Chapter 59 in *Vascular Surgery* 4th Ed (ed by Rutherford) WB Saunders, Co., Philadelphia, 1995; 874-83.
5. Casten DF, Sadley AH, Foreman D. An experimental study of sympathectomy or patency of small vessel anastomoses. *Surg Gynecol Obstet* 1962; 114:462.
6. Weissenhofer W, Schenk WG Jr. Hemodynamic response to vasodilation and exercise in "critical" arterial stenosis. *Arch Surg* 1974; 108:712.
7. Moore WS, Hall AD. Effects of lumbar sympathectomy on skin capillary blood flow in arterial occlusive disease. *J Surg Res* 1974; 14:151.
8. Walker PM, Johnston KW. Prediction of the success of a sympathectomy: A prospective study using discriminating function and multiple regression analysis. *Surgery* 1980; 87:216.
9. Yao JST, Bergan JJ. Predictability of vascular reactivity to sympathetic ablation. *Arch Surg* 1973;

107:676.

10. DeValle MJ, Bauma FG, Mintzer R, et al. Limited success of lumbar sympathectomy in the prevention of ischemic limb loss in diabetic patients. *Surg Gynecol Obstet* 1981; 152:784.
11. Shionaoya S. Buerger's disease. Pathology diagnosis and treatment. The University of Nagoya Press. 1990.
12. Mills JL, Friedman EI, Taylor LM Jr, et al. Upper extremity ischemia caused by small artery disease. *Ann Surg* 1987; 154:123.
13. Machleder HI, Wheeler E, Barber WF. Treatment of upper extremity ischemia by cervicodorsal sympathectomy. *Vasc Surg* 1979; 13:399.
14. Flatt AE. Digital artery sympathectomy. *J Hand Surg* 1980; 5:550.
15. Lee BY, Brancato RF, Thoden WR, et al. Blue digit syndrome: Urgent indication for digital salvage. *Ann J Surg* 1984; 147:418.
16. Mehigan JT, Stoney RJ. Lower extremity atheromatous embolization. *Am J Surg* 1976; 132:163.
17. Mockus MB, Rutherford RB, Rosales C, et al. Sympathectomy for causalgia: patient selection and long-term results. *Arch Surg* 1987; 122:668.
18. Malone PS, Cameron ALP, Rennie JA. Endoscopic thoracoscopic sympathetic in the treatment of upper limb hyperhidrosis. *Ann Coll Surg Engl* 1986; 68:93.
19. Appleby TC, Edwards WH Jr. Thoracoscopic dorsal sympathectomy for hyperhidrosis. Technique of choice. *J Vasc Surg* 1992; 16:121.
20. Ramos M, Almazan A, Lozano F, et al. Phenol lumbar sympathectomy in severe arterial disease of the lower limb. A hemodynamic study. *Int Surg* 1983; 68:127.
21. Cross FW, Cotton LT. Chemical lumbar sympathectomy for ischemic rest pain. A randomized prospective controlled clinical trial. *Am J Surg* 1985; 150:341.
22. Weinstein MH, Machleder HI. Sexual function after aorto-iliac surgery. *Ann Surg* 1975; 181:787.

## 25. Portal Hypertension

Robert W. Hobson, III, M.D.

### I. Anatomy and Pathophysiology

1. Describe the anatomy of the liver and its portal and arterial circulations.
2. Understand the relationships of extra- and intrahepatic pathological abnormalities resulting in portal hypertension and a tendency to variceal bleeding secondary to the elevations in portal pressure.
3. Define the limits of portal pressure and its influence on variceal bleeding.
4. Understand the physiology of increased splanchnic blood flow observed in the later stages of intrahepatic and extrahepatic disease. The importance of splanchnic vasodilation and its contribution to portal hypertension should be appreciated.
5. Understand the hemodynamics associated with the portal hypertension syndrome to include decreases in mean arterial pressure and peripheral resistance, while increases in cardiac index and output are observed. As a result of an associated peripheral vasodilation, describe the neurohumoral pathways which are activated leading to sodium retention, expansion of plasma volume, and increased arterial pressure and cardiac output.

### II. Etiology

1. Describe intrahepatic and extrahepatic (pre- and posthepatic) causes of obstruction to the portal circulation.
2. Understand the causes of portal hypertension which are extrahepatic, intrahepatic, sinusoidal and hepatic venous in etiology. Categorize portal vein thrombosis, schistosomiasis, cirrhosis, and Budd-Chiari syndrome in this classification.
3. Understand and define the determinants of variceal bleeding.

### III. Diagnostic Evaluation

1. Define the Child's classification
2. Understand the clinical evaluation of the portal hypertensive patient and describe the stigmata of liver disease detailed during a history and physical examination.
3. Describe the importance of liver function studies in the Child's classification.
4. Understand angiographic imaging of the portal vein by selective splanchnic angiography. Alternative techniques including computed tomography and magnetic resonance imaging may also contribute and should be understood in the evaluation of these patients.
5. Describe the role for hemodynamic measurements including wedge hepatic venous pressure as well as duplex imaging of the portal vein.

### IV. Management

1. Control of acute variceal bleeding.
  - a. Understand the circumstances of variceal bleeding, its mortality in relationship to the Child's classification, and the natural history of bleeding.
  - b. Understand the role of fluid management, pharmacological treatment with splanchnic vasoconstrictors (vasopressin), vasodilators (nitroglycerin) and other pharmacologic agents.
  - c. Understand the role of the Sengstaken-Blakemore and Linton tubes in the control of acute variceal bleeding.
  - d. Describe the value of endoscopic sclerotherapy in the management of acute variceal bleeding. Understand the efficacy and timing as well as the technique used for endoscopic injection.
  - e. Describe endoscopic variceal band ligation and percutaneous transhepatic embolization in the control of variceal bleeding.
2. Surgical Management of Portal Hypertension

- a. Understand the historical development of the Eck fistula and its impact on the surgical management of portal hypertension.
  - b. Understand the difference between total portal-systemic shunts and selective (distal splenorenal) shunts.
  - c. Describe the non-shunt surgical management of varices including the Womack and Sugiura procedures.
  - d. Describe the development and use of intrahepatic shunts (transjugular intrahepatic portosystemic shunts-TIPS).
  - e. Describe the advantages of the TIPS procedure for acute variceal bleeding and the anticipated mortality when compared with portal-systemic shunts.
  - f. Understand the role of liver transplantation in patients with portal hypertension and variceal bleeding.
- V. Describe a current clinical algorithm for the management of variceal hemorrhage.
- a. Understand the role of early endoscopic diagnosis in the control of variceal bleeding.
  - b. Understand that endoscopic sclerotherapy will control the majority of patients with acute variceal bleeding, while balloon tamponade or TIPS may be required in the remainder of patients.
  - c. Understand options for non-alcoholic and alcoholic patients with controlled or recurrent bleeding: selective variceal decompression with distal splenorenal shunt, sclerotherapy with or without pharmacological agents, and liver transplantation.

#### References

1. Benoit JN, Granger DN. Splanchnic hemodynamics in chronic portal venous hypertension. *Semin Liver Dis* 1986; 6:287.
2. Bosch J. Effect of pharmacological agents on portal hypertension: A hemodynamic appraisal. *Clin Gastroenterol* 1985; 14:169.
3. Bosch J, Navasa M, Garcia-Pagan JC, et al. Portal hypertension. *Med Clin North Am* 1989; 73:931.
4. Corriea PJ, Alves MM, Alexandrio P, et al. Controlled trial of vasopressin and balloon tamponade in bleeding esophageal varices. *Hepatology* 1984; 4:885.
5. Crafoord c, Frenchner P. New surgical treatment of varicose veins of the esophagus. *Acta Otolaryngol* 1939; 27:422.
6. Eck NV. On the question of ligature of the portal vein. *Voen Med Zh* 1877; 130:1. Translation in: *Surg Gynecol Obstet* 1953; 96:375.
7. Grace ND. Prevention of recurrent variceal bleeding - is surgical rescue the answer? *Ann Intern Med* 1990; 112:242.
8. Graham D, Smith JL. The course of patients after variceal hemorrhage. *Gastroenterology* 1981; 80:800.
9. Henderson JM, Gilmore GT, Hooks MA, et al. Selective shunt in the management of variceal bleeding in the era of liver transplantation. *Ann Surg* 1992; 216:248.
10. Hunt PS, Korman MG, Hansky J, et al. An 8-year prospective experience with balloon tamponade in emergency control of bleeding esophageal varices. *Dig Dis Sci* 1982; 27:413.
11. Jones AL, Schmucker DL. Current concepts of liver structure as related to function. *Gastroenterology* 1977; 73:833.
12. Keagy BA, Schwartz JA, Johnson IG. Should ablative operations be used for bleeding esophageal varices? *Ann Surg* 1986; 203:463.
13. Lunderquist A, Vang J. Transhepatic catheterization and obliteration of the coronary vein in patients with portal hypertension. *N Engl J Med* 1974; 291:646.
14. Mahl TC, Groszmann RJ. Pathophysiology of portal hypertension and variceal bleeding. *Surg Clin North Am* 1990; 70:251.

15. McCain AH, Bernardino ME, Sones PJ Jr, et al. Varices from portal hypertension: Correlation of CT and angiography. *Radiology* 1985; 154:63.
16. Nordlinger BM, Nordlinger DF, Fulenwider JT, et al. Angiography in portal hypertension: Clinical Significance in Surgery. *Am J Surg* 1980; 139:132.
17. Okuda K, Takayasu K, Iwanoto S. Angiography in the diagnosis of liver disease. *Semin Liver Dis* 1989; 9:50.
18. Panes J, Teres J, Bosch J, et al. Efficacy of balloon tamponade in treatment of bleeding gastric and esophageal varices: Results in 151 consecutive episodes. *Dig Dis Sci* 1988; 33:454.
19. Reyes J, Iwatsuki S. Current management of portal hypertension with liver transplantation. *Adv Surg* 1992; 25:189.
20. Sherlock S. Classification and functional aspects of portal hypertension. *Am J Surg* 1974; 127:121.
21. Silpo ML, Jensen DM, Machido GA, et al. Efficacy and safety of agents for variceal sclerotherapy. *Gastrointest Endosc* 1982; 28:253.
22. Steigmann GV, Cambre Am, Sun JH. A new endoscopic elastic band ligating device. *Gastrointest Endosc* 1986; 32:230.
23. Sugiura M, Futagawa S. A new technique for treating esophageal varices. *J Thorac Cardiovasc Surg* 1973; 66:677.
24. Terblanche J. The surgeon's role in the management of portal hypertension. *Ann Surg* 1989; 209:381.
25. Warren WD. Control of variceal bleeding. Reassessment of rationale. *Am J Surg* 1983; 145:8.