# Essential Interventional Radiology Review

## A Question and Answer Guide

Rajat Chand · Adam E. M. Eltorai · Terrance Healey · Sun Ahn *Editors*

Springer

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# Preface

## What Is Interventional Radiology?

One of the newest primary medical specialties, as recognized by the American Board of Medical Specialties, interventional radiology (IR) is a field within radiology that offers minimally invasive diagnostic and treatment strategies for a broad range of illness. IR is proven to provide effective treatment options, generally associated with lower surgical risk, complications, and overall morbidity. Often considered to intersect clinical care, minimally invasive procedures, and radiologic diagnosis and guidance, IR practitioners have the unique opportunity to partake in the care of many different disease processes, as well as partake in cutting-edge and groundbreaking research. Since the field's inception, when the radiologists Seldinger and Dotter laid the path for minimally invasive procedures, IR has today become a primary specialty of medicine that provides any IR practitioner the opportunity for a career filled with rich patient interaction experienced through longitudinal clinical care. The core principles of this field and its society are to: expand access to the high-quality care IRs can provide, continuously translate innovation into better patient outcomes, provide comprehensive and lifelong education to practitioners at all levels, and always work alongside other medical specialties to thrive for the best possible outcomes for patients.

## Using this Book

This review-style book is written in a question-and-answer format for medical students and residents to utilize during their interventional radiology rotation. It is designed to be a quick reference, as well as a tool for independent study, and covers many general and subspecialty topics in interventional radiology. As it would be impossible to provide the complete breadth of education for all disease processes interventional radiologists treat in this single text, our goal is rather to provide a resource to help accurately answer many on-the-spot questions, which are commonly encountered during procedures and clinical management.

*Essential Interventional Radiology Review* is organized to first offer some basic knowledge to help acquaint the reader with important clinical and technical considerations of the IR workspace, and then focuses on system-based review. The span of content covers most of the commonly encountered pathologies in IR, as well as some emerging techniques. We hope this book serves as a convenient resource and aids in contributing pearls to all of the rich, educational discussions taking place in IR training programs across the world.

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# Part I
# Daily Workflow

# Chapter 1
# The Role of a Subintern

**Chris Molloy and Junjian Huang**

The purpose of the subinternship (some institutions may refer to this as Sub-I, acting intern, or AI) is to allow fourth year medical students to assume a greater role in the direct care of patients in IR. Taking on increased responsibility empowers medical students to more actively engage in the care of their patients, as well as to demonstrate their decision-making and patient management skills to the medical team. A subintern's responsibility includes performing consultation, rounding on IR patients, pre-procedural workup and evaluation, understanding of relevant pathophysiology, assisting in procedures, and post-procedural and longitudinal care. The subinternship is an opportunity to spend time reading about and becoming familiar with expert-level anatomy, the various pathologies encountered and indications for intervention, as well as the vast array of tools that will be encountered on the back table. A subintern should maintain a

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professional attitude and espouse team work at all times. Included in the below chapters are a range of questions that provide only a sample of the breadth of knowledge and curiosity that should be sparked within the IR rotation.

| | |
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| What imaging modalities are used during interventional radiology procedures? | Ultrasound, fluoroscopy, CT, and/or MRI |
| How is fluoroscopy different from general radiography (X-ray)? | Fluoroscopy utilizes lower milliampere (mA) voltage as compared to X-ray, as well as pulsed radiation to compensate for the longer necessary exposure time |
| What measures are taken to minimize radiation exposure of interventional radiologists? | Lead gowns, lead-lined eyeglasses, shields, ALARA (as low as reasonably achievable), etc. Radiation exposure is monitored monthly to avoid excess of the recommended limit. |
| How many French (Fr) are in 1 mm? | 3 Fr = 1 mm or 1 Fr = 0.33 mm. Sheath sizes are defined by their inner diameter. Catheters and wire sizes are defined by their outer diameter. The size of an arteriotomy or venotomy created by a sheath is approximately 1.5–2 Fr larger than the labeled sheath size. |
| How are sheaths, wires, and catheters described in terms of size? | Sheaths are described in French sizes, indicative of the inner diameter, and total length<br>Wires and catheters are described in French sizes (catheters) and inches (wires), indicative of outer diameter. The length of all of these devices is described in centimeters |
| According to Poiseuille's law, what has greatest impact of flow through a tube? | According to the law, a change in radius corresponds to a proportional change in flow by a factor of the fourth power Flow is also directly proportional to the change in pressure. Smaller-bore catheters will require a greater change in pressure to be able to maintain forward flow of the contents |

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| What is the mechanism of action and plasma half-life of unfractionated heparin? | Heparin binds to and activates the enzyme antithrombin III, which then binds to and inactivates thrombin and factor Xa. The half-life is 60–90 min. Approximately 1 mg of protamine sulfate will inactivate 100 units of heparin. |
| What is the mechanism of action and plasma half-life of low molecular weight heparin (LMWH)? | LMWH also inactivates thrombin and factor Xa. The half-life of protamine is 7 min and, therefore, LMWH lends itself to repeat dosing. |
| What pharmacological agent can be used in patients with heparin allergy? | Direct thrombin inhibitors, such as bivalirudin, argatroban and dabigatran. Bivalirudin requires dose adjustment for renal impairment and is not monitored with ACT. Argatroban and dabigatran undergo hepatic clearance and can be monitored with ACT. Bleeding complications for these agents can be treated using recombinant factor VIIa. |
| What is the goal for therapeutic anticoagulation during interventional procedures? | A baseline "activated clotting time" (ACT) should be established before relevant procedures. Anticoagulation is considered therapeutic when the ACT is 1.5–2 times above the baseline |
| What medication may improve coagulation in patients with uremic platelet dysfunction? | DDAVP (desmopressin) |
| What is used to reverse the effects of midazolam (benzodiazepine)? | Flumazenil |
| What is used to reverse the effects of fentanyl (opiate based narcotic)? | Naloxone |
| What doses of midazolam and fentanyl are typically given during moderate sedation? | IV bolus doses of 25–100 mcg of fentanyl and 0.5–2 mg midazolam, respectively, are given. Chronic pain medication use may require higher doses of fentanyl. |
| What is the relative duration of effect of fentanyl and midazolam? | Fentanyl and midazolam have a relatively long duration of effect, 30–60 and 30–80 min, respectively. It is important to remember that the level of sedation may deepen even after the procedure. |

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| What factors must always be kept in mind for patients receiving sedation and analgesia? | Any major comorbidities<br>Any abnormalities of the airway (does the patient have a known or suspected difficult airway?)<br>Tolerance to pain medications<br>Obesity or history or obstructive sleep apnea<br>Will the case require prone positioning?<br>Does the patient have claustrophobia? |
| What is the antibiotic coverage of vancomycin? | Gram positive, including MRSA |
| What is the antibiotic coverage of piperacillin-tazobactam (Zosyn)? | Gram positive, negative, anaerobe. Not MRSA or fungus |
| What can be added to penicillins, ampicillin (IV), and amoxicillin (PO) to create broad coverage? | Beta-lactamase inhibitors; clavulanic acid (Augmentin or amoxicillin-clavulanate) and sulbactam (Unasyn or ampicillin-sulbactam) |
| What are the third-generation cephalosporins? | Ceftazidime and ceftriaxone are third-generation cephalosporins with lower efficacy against gram-positive organisms as compared to first- and second-generation cephalosporins, but with broad gram-negative coverage |
| Which cephalosporin will treat *Pseudomonas*? | Cefepime is a fourth-generation cephalosporin with gram-negative only coverage, including *Pseudomonas* |
| Which antibiotics have good anaerobe coverage? | Clindamycin provides good anaerobe coverage for organism encountered on the skin, head, and neck. Metronidazole provides good GI/GU anaerobe coverage |
| What is a good antibiotic choice to treat cellulitis? | Start with a first- or second-generation cephalosporin<br>Consider options, such as vancomycin (MRSA), clindamycin (MRSA and anaerobes), or TMP/SMX if cephalosporins fail |
| What are the main types of medical shock that patients may encounter? | Septic, hypovolemic, cardiogenic, neurogenic, and anaphylactic |

What are the major signs and symptoms of shock?

| Type | RR | HR | BP | Skin | Temp | Urine | Other |
|---|---|---|---|---|---|---|---|
| Anaphylactic | ↑↓ | ↑ | ↓ | Flushed, swollen, itchy | No Change | ↓ | Urticaria, pruritus, bronchoconstriction |
| Cardiogenic | ↑ | ↑ | ↓ | Pale, cool, clammy | No Change | ↓ | Chest discomfort, syncope, JVD, pulmonary edema, orthopnea |
| Hypovolemic | ↑ | ↑ | ↓ | Pale, cool, clammy | No Change | ↓ | Anxiety, thirst, syncope, weakness, confusion, dizziness, weak pulse |
| Obstructive | ↑ | ↑ | ↓ | Pale, cool, clammy | ↓ | ↓ | Muffled heart sounds, JVD, decreased LOC, signs of poor perfusion |
| Neurogenic | ↑ | ↓ | ↓ | Warm, flushed, dry | ↑↓ | No bladder control | Paralysis distal to injury site, priapism |
| Septic (Distributive) | ↑ | ↑ | ↓ | Flushed, then pale and cool | ↑↓ | ↑ | Bounding pulse, altered LOC |

What clinical features further define certain forms of shock?

| Type | MAP | CO | DO2 | CVP | MPAP | PCWP | SVR |
|---|---|---|---|---|---|---|---|
| Cardiogenic | ↓/– | ↓ | ↓ | ↑ | ↑ | ↑ | ↑ |
| Hypovolemic | ↓/– | ↓ | ↓ | ↓ | ↓ | ↓ | ↑ |
| obstructive | ↓ | ↓ | ↓ | ↑ | ↑ | ↑ | ↑ |
| Septic (Distributive) | ↓ | ↑ | ↑ | ↓ | ↓ | ↓ | ↓ |

What conditions require emergent IR intervention?

Acute ischemia (limb, end-organ, pulmonary embolus, etc.), hemorrhage (hemoptysis, hematemesis, ruptured aneurysm, traumatic, iatrogenic, etc.), closed-space infections (pyonephrosis, cholangitis, abscess, etc.)

How do you know if a patient can provide their own consent?

The patient must be (1) alert; (2) oriented; (3) be able to understand and ideally reiterate the risks, benefits, and alternatives of procedure; and (4) have legal capacity

What are the current Anesthesia Society of America (ASA) guidelines for eating and drinking prior to procedures performed with moderate sedation?

No solid foods 6 h prior to procedure
No clear fluids for 2 h prior to procedure

Where would you find prophylactic antibiotic recommendations for planned procedures?

The 2019 Society of Interventional Radiology (SIR) Antibiotic Prophylaxis Guidelines during Procedures

Where would you find recommendations regarding holding anticoagulation prior to planned procedures?

The 2019 Society of Interventional Radiology (SIR) Periprocedural Anticoagulation Guidelines

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| What are the ASA classifications? | Class I: Normal healthy patient<br>Class II: Mild systemic disease<br>Class III: Severe systemic disease<br>Class IV: Severe systemic disease which is a constant threat to life<br>Class V: Moribund patient who is not expected to survive without the procedure<br>Class VI: Declared brain-dead patient whose organs are being removed for donor purposes |
| What is the modified Mallampati score? | Class I: Soft palate, uvula, fauces, pillars visible<br>Class II: Soft palate, major part of uvula, fauces visible<br>Class III: Soft palate, base of uvula visible<br>Class IV: Only hard palate visible |
| What are the differences between nasal cannula, venturi mask, non-rebreather, and high-flow nasal cannula (HFNC)? | Nasal cannula: Provides oxygen at a low flow rate<br>Venturi: Controls/restricts the amount of entrained air and therefore the FiO2<br>Non-rebreather: Delivers the highest FiO2 at standard flow rates<br>HFNC: Provides warmed, humidified supplemental oxygen at a rate of up to 60 L/min<br>Remember that supplemental oxygen will not treat hypercapnia due to alveolar hypoventilation and may misleadingly raise pulse oximetry readings |
| What scoring system may be used to stratify atherosclerotic cardiovascular risk? | Atherosclerotic Cardiovascular Disease (ASCVD) risk calculator from the AHA/ACC |
| What is the main clinical patient assessment tool used in the evaluation of acute stroke? | The NIHSS score describes the physical limitations caused by the acute stroke. Neurologic impairment is classified based on its severity and extent. The scale is between 0 and 42 with higher scores (≥21) indicating a severe stroke |
| What is the classification system for acute and chronic limb ischemia? | Rutherford |

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| What is the Couinaud system of liver segmentation? | The liver is divided inferiorly and superiorly by the portal vein. The right and left hepatic lobes are divided by the falciform ligament, which contains the obliterated umbilical vein (ligamentum teres), the falciform artery, and the paraumbilical veins. The hepatic vein borders define the Couinaud segments: superiorly left-to-right, 2, 4a, 8, and 7 and inferiorly left-to-right, 3, 4b, 5, and 6. The middle hepatic vein should intersect the gallbladder fossa |
| Name the locations of the various types of varices that may be found related to portal hypertension | Left gastric venous collaterals<br>Esophageal<br>Paraesophageal<br>Recanalized paraumbilical vein<br>Abdominal wall<br>Perisplenic<br>Retrogastric<br>Omental<br>Retroperitoneal-paravertebral<br>Mesenteric<br>Sites of previous surgery or inflammation |
| Patients with chronic mesenteric vessel occlusion may demonstrate collateral vascular pathways. What are the common mesenteric collateral pathways? | Arc of Buhler: remnant artery that directly connects the proximal celiac artery with the proximal superior mesenteric artery (SMA)<br>Arc of Riolan (mesenteric meandering artery [of Moskowitz] or central anastomotic mesenteric artery): collateral path from the middle colic branch of the SMA to the left colic branch of the inferior mesenteric artery (IMA)<br>Marginal artery of Drummond: connects the terminal branches of the SMA and IMA<br>Pancreatic cascade: connects superior pancreaticoduodenal artery branches of the gastroduodenal artery (GDA) to the inferior pancreaticoduodenal branches of the SMA<br>Arc of Barkow (gastroepiploic cascade, arcus epiploicus magnus): collateral path connecting the right gastroepiploic (branch of the GDA) to the left gastroepiploic (branch of the splenic artery) |

# Chapter 2
# Presenting a Patient

**Chris Molloy and Junjian Huang**

Different attending physicians will prefer different forms of presentation. These variations are often based on the individual attending preference, but variations in presentation may also be commonly driven by the type of specialty or form of disease. Since interventional radiology is a clinical and procedural specialty, students and residents will likely be expected to present relevant history with pertinent negative findings, specific disease-related lab results, and key findings from diagnostic imaging and prior interventions with close attention to patient-specific anatomy and specifications of the prior tools used in treatment.

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| What key lab findings are important for chronic kidney disease patients prior to image-guided procedures? | PT/INR, platelets, GFR, and BUN (uremic platelet dysfunction leads to prolonged bleeding) |
| How can symptoms of acute arterial ischemic stroke be differentiated from other causes of ischemic cerebral pathology? | Acute arterial ischemia disease manifestation is related to the acute drop in glucose and oxygen delivery, with the extent of damage reliant upon the degree of ischemia and ability to recruit collateral vasculature<br>Central retinal artery occlusion (CRAO) presents as painless monocular vision loss with a cherry red spot visible on fundoscopic examination<br>Cerebral venous sinus thrombosis (CVST) manifests as symptoms related to impaired venous drainage, including headache, blurred vision, painful loss of vision, loss of bodily control, seizure, and coma |
| What imaging finding may indicate increased bleeding risk during percutaneous liver biopsy? | The presence of ascites increases the risk of intraperitoneal hemorrhage. These patients should either receive paracentesis prior to percutaneous liver biopsy or be offered a transjugular liver biopsy instead. |
| What medical therapy should be considered in large-volume paracentesis (>5 L ascitic fluid removal)? | An albumin infusion of 6–8 g/L of fluid removal improves survival |
| What other disease processes affect chronic limb ischemia patients? | Myocardial infarction (25% in 5 years), stroke |

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| What medications should chronic limb ischemia patients be on? | Aspirin, beta-blocker, high-intensity statin, ACE inhibitor, +/– cilostazol |
| What are disadvantages of duplex ultrasound to CTA in pre-procedural evaluation of limb ischemia intervention? | Though less expensive, duplex ultrasound has less spatial resolution than CT and can be limited by operator experience and body habitus. Calcium can pose a problem for both modalities. Typically, if a patient has palpable and symmetric femoral pulses, CTA can be avoided. |
| Will endograft stent placement fix type 2 endoleaks? | No. Balloon remodeling and endograft stent placement are treatment options for type 1 endoleaks, which are caused by inadequate seal at the proximal or distal stent attachment sites. Embolization is the first-line treatment for type 2 endoleaks. |
| What scoring system may be used to predict pulmonary embolism (PE) 30-day outcomes? | Simplified Pulmonary Embolism Severity Index (PESI) score may be used to determine and stratify severity of PE:<br>Class I = score ≤ 65 (1.1% 30-day mortality)<br>Class II = score 66 – 85 (3.1% 30-day mortality)<br>Class III = score 86 – 105 (6.5% 30-day mortality)<br>Class IV = score 106 – 125 (10.4% 30-day mortality)<br>Class V = score > 125 (24.5% 30-day mortality) |

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| The PESI score is divided into which demographic, comorbid illness, and clinical finding predictors? | Age (1 pt./yr.)<br>Male (10 pts.)<br>Cancer (30 pts.)<br>Heart failure (20 pts.)<br>Chronic lung disease (20 pts.)<br>AMS (60 pts.)<br>SBP < 100 mmHg (30 pts.)<br>HR ≥ 110 (20 pts.)<br>RR ≥ 30 (20 pts.)<br>Temp < 36 °C (20 pts.)<br>Arterial oxygen saturation <90% (20 pts.) |
| What antibiotics should patients be given prior to cholangiogram? | Ceftriaxone or cefotetan (unless the patient is allergic, in which case another option, such as vancomycin or clindamycin + an aminoglycoside may be used) |
| What is the initial medical management of a chyle leak? | Chyle leaks may be post-traumatic or iatrogenic in nature and should be initially managed with low-fat diet or TPN, octreotide infusion, and percutaneous drainage |
| What are the components of MELD-Na score? | Creatinine, bilirubin, INR, and serum sodium |
| What is APACHE II used for and what do the letters in APACHE represent? | APACHE II helps to determine severity of disease and mortality prediction of ICU patients<br>The acronym APACHE is "Acute Physiology and Chronic Health Evaluation" |
| Where is the most common location where dialysis graft stenosis occur? | At the graft-vein anastomosis |

| | |
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| Where is the most common location that dialysis fistulas stenose/occlude? | Peri-anastomotic venous outflow |
| What is the estimated rate of IVC filter-induced thrombus? | 2–10% |
| What is the best CT protocol to visualize aortic intramural hematoma? | Non-contrast CT images are ideal to detect for high-density intramural aortic collections. Useful CT protocols in evaluation of aortic and arterial pathology include non-contrast, arterial phase, and delayed phase images. |
| What are the components of the Child-Pugh score? | Bilirubin, albumin, total protein, ascites, and hepatic encephalopathy |
| What is a SAAG score and how do you interpret it? | SAAG is the serum to ascites albumin gradient. A value > 1.1 g/dL indicates hepatic causes of the ascites, such as cirrhosis with portal hypertension and, less commonly, CHF. A value < 1.1 g/dL indicates malignancy or infection. |

# Chapter 3
# Morning Rounds

**Chris Molloy and Junjian Huang**

Morning rounds or morning report is typically comprised of discussion of all scheduled patients, including treatment plans, a review of call cases from the previous night or weekend, and review of patients on the IR service and/or consult service. During morning report, individuals often give a very brief "one-liner" history and procedure to be performed and discuss any pertinent lab/imaging concerns. For more complicated cases, this brief discussion may also include planned access or path, device discussions, collaboration with other departments, and additional needs, such as anesthesia.

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| What is the most common risk in patients with popliteal aneurysms? What additional findings may be seen in patients with popliteal aneurysm? | Patients with popliteal aneurysms have a high risk of thromboembolism<br>50% of popliteal aneurysms are bilateral<br>Approximately 25% of patients with popliteal aneurysms also have an aortic aneurysm (<10% of patients with aortic aneurysms have popliteal aneurysms) |
| How often should vitals, neurovascular checks, and groin check be performed following mechanical thrombectomy for stroke? | Q 15 min × 2, Q 30 min × 6, Q hourly × 16 |
| What is the 90-day stroke risk following TIA? | Very broad range, 8–77%, with half occurring within the first 7 days<br>50% of those who experience a TIA will have a stroke within 1 year<br>15% of all strokes are heralded by a TIA |
| During ultrasound evaluation of a TIPS, what are normal expected flow velocities? | TIPS stenosis is marked by globally decreased velocity (< 40–60 cm/s) within the shunt and focally increased velocity (> 200 cm/s) at the point of stenosis |
| What is Kasabach-Merritt syndrome? | Kasabach-Merritt syndrome (hemangioma thrombocytopenia syndrome) is found in infants with large, highly vascular hemangiomas and is responsible for thrombocytopenia, microangiopathic hemolytic anemia, and consumptive coagulopathy |

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| What is May-Thurner syndrome? | Classic May-Thurner syndrome is compression of the left common iliac vein (CIV) by the right common iliac artery resulting in decreased CIV vessel diameter by 50%. A physiologic pre-stenotic to post-stenotic gradient of 2–3 mmHg gradient has also been suggested but has not been validated. Treatment includes clot lysis and stenting |
| What are expected angiographic findings in median arcuate ligament syndrome (MALS)? | MALS is characterized by extrinsic compression of the celiac artery by the median arcuate ligament:<br>During inspiration, as the diaphragm and abdominal contents move down, compression on the superior aspect of the celiac artery by the MAL. The celiac artery will appear widely patent on the lateral projection<br>During expiration, the diaphragm and abdominal contents will move up and worsen the effect compression on the celiac artery by the MAL, which will be evident by focal narrowing on the lateral angiographic projection |
| What are typical physical exam findings in popliteal artery entrapment syndrome (PAES)? | Diminished distal lower extremity pulses with plantar or dorsiflexion |
| What is a normal portal-systemic gradient? | ≤ 6 mmHg. Symptomatic manifestations of portal hypertension are usually not encountered until > 10 mmHg. |
| At what portal-systemic gradient do patients usually experience variceal bleeding? | ≥ 12 mmHg |

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| What are the Milan criteria? | Milan Criteria used in patients with hepatocellular carcinoma to assess suitability for liver transplantation:<br>A single tumor with diameter ≤5 cm, or up to 3 tumors (each tumor diameter must be ≤3 cm)<br>No extrahepatic involvement<br>No portal vein extension |
| How many MELD "exception points" do hepatocellular carcinoma (HCC) patients receive (while waiting for liver transplant)? | After 6 months within Milan criteria, HCC patients are given a minimum of 28 MELD points (however these "exception points" are subject to change in future iterations of OPTN transplant protocol) |
| What medications may be administered to reduce hepatic encephalopathy in patients with cirrhosis and liver failure? | Lactulose (15–45 ml every 8–12 h) titrated to 3 soft bowel movements per day<br>Rifaximin (550 mg orally BID) |

# Chapter 4
# Afternoon Rounds

**Chris Molloy and Junjian Huang**

In some facilities, afternoon rounds may be an opportunity to discuss discharge planning or post-procedural dispositions.

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| What does qSOFA score evaluate and how do you calculate it? | Quick sequential organ failure assessment score (qSOFA) score of 2 (or more) at the onset of infection is associated with a greater risk of death or prolonged intensive care unit stay.<br>qSOFA score includes:<br>Altered mental status<br>Respiratory rate > 22<br>Systolic BP ≤ 100 |

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| What is SIRS and what are the components of SIRS score? | Systemic inflammatory response syndrome (SIRS) describes whole body response to infectious or noninfectious insult. Note that the JAMA SOFA/qSOFA report advocates replacing SIRS with SOFA in specific situations:<br>Temperature < 36 °C or > 38 °C<br>Heart rate > 90 bpm<br>Tachypnea > 20 respirations per minute<br>WBC < 4000 cells/$mm^3$<br>or > 12,000 cells/$mm^3$ |
| A patient that your team treated for PAD now has a rapid decline in platelets from 200,000 to 75,000. What is the most likely diagnosis and how do you proceed? | The diagnosis is probably heparin-induced thrombocytopenia (HIT). The treatment is to discontinue heparin products. Maintain anticoagulation with non-heparin products, such as direct thrombin inhibitors (IV argatroban or PO dabigatran). Warfarin should not be started until platelets recover to $\geq 150 \times 10^9$/L. |
| Your team placed an infusion catheter in order to perform prolonged tPA infusion to treat acute pulmonary embolism. The plan is to keep the catheter in place for at least 12 h. What labs should you order to follow this patient? | Hemoglobin, hematocrit, and fibrinogen q6h. If the fibrinogen level drops to < 150 (or decreases by 1/2), the tPA infusion may be decreased by 1/2 dose. If the fibrinogen level is < 100 or the patient has severe bleeding, the infusion is discontinued |
| What recommendations and medications should be considered in PAD patients? | Smoking cessation<br>Supervised exercise program<br>Aspirin or clopidogrel (Plavix)<br>Beta-blocker<br>ACE inhibitor<br>High-intensity statin<br>Cilostazol |

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| What are the goals of medical therapy after intervention for limb ischemia? | To reduce cardiovascular morbidity and mortality, as well as reduce adverse limb outcomes |
| What are the main findings and recommendations from the CLEVER trial? | Supervised exercise and stent had better 18-month outcomes than optimal medical care. Intermittent exercise and rest improves oxygen extraction. Exercise also improves endothelial function, blood pressure, cholesterol, glycemic control, and overall functional capacity. Supervised exercise involves 30–45 min sessions, 3 times a week, for 12 weeks. Patients are instructed to walk until there is pain, persist as much as possible, and then rest. Only walking minutes are counted. Supervised exercise therapy improves walking time, functional status, and quality of life. It also increases the size and number of collaterals. |
| What was the conclusion of the 2002 Antithrombotic Trialists' Collaboration for high-risk patients for occlusive vascular events (acute MI or ischemic stroke, unstable or stable angina, previous MI, stroke or cerebral ischemia, PAD, or atrial fibrillation)? | 287 studies involving 135,000 patients in comparison with antiplatelet therapy vs. control and 77,000 patients in comparison with different antiplatelet regimens. Aspirin is protective in high-risk patients and low dose (75–150 mg daily) is effective for long-term use, but in an acute setting, an initial loading dose of at least 150 mg may be required |

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| What were the findings of the "Clopidogrel versus Aspirin in Patients at Risk of Ischemic Events" (CAPRIE) study? | This was a multicenter, multinational, randomized, double-blind, parallel group analysis of 19,185 patients with atherosclerotic disease (recent ischemic stroke, recent MI, or symptomatic PAD) with primary combined endpoint of ischemic stroke, MI, or vascular death and 1.9-year mean follow-up:<br>Approximately 9% additional relative risk reduction in primary combined endpoint with clopidogrel versus aspirin<br>Approximately 9% additional relative risk reduction in cumulative rehospitalization rate for ischemia or bleeding with clopidogrel versus aspirin |
| What were the findings of the EUCLID study (Ticagrelor versus Clopidogrel in Symptomatic in Peripheral Artery Disease)? | Symptomatic PAD (and clinically significant ABI or prior lower extremity revascularization) was randomized to ticagrelor 90 mg twice daily ($n$ = 6930) versus clopidogrel 75 mg daily ($n$ = 6955):<br>Ticagrelor was not superior to clopidogrel in preventing major adverse cardiac events<br>Acute limb ischemia and major bleeding were similar between treatment groups |

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| The purpose of the COMPASS trial was to evaluate whether treatment with rivaroxaban and aspirin or rivaroxaban alone is better than aspirin alone in prevention of MI, ischemic stroke, or cardiovascular death in patients with coronary or peripheral arterial disease. What medical therapy would you recommend for a patient with history of revascularization and low bleeding risk? | Randomized, placebo-controlled study of 27,400 patients with CAD, carotid stenosis, and PAD with primary endpoints of MI, ischemic stroke, cardiovascular death, and major bleeding:<br>In patients with atherosclerotic cardiovascular disease, rivaroxaban plus aspirin resulted in lower rates of composite cardiovascular endpoint events but higher rates of major bleeding than with aspirin alone<br>Major adverse limb events were increased in those with history of prior revascularization compared to claudicants or asymptomatic PAD<br>In subgroup analysis, those with polyvascular disease benefit the most |
| What were the findings of Evaluating Adverse Events in a Global Smoking Cessation Study (EAGLES)? | This was a randomized, double-blind, triple dummy, placebo-controlled, and active-controlled trial (nicotine patch 21 mg/day with taper) of those receiving varenicline 1 mg PO BID or bupropion 150 mg PO BID:<br>The study did not show a significant increase in neuropsychiatric adverse events attributable to varenicline or bupropion relative to nicotine patch or placebo<br>Varenicline was more effective than placebo, nicotine patch, and bupropion in helping smokers achieve abstinence, whereas bupropion and nicotine patch were more effective than placebo |

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| What were the findings of the "Heart Outcomes Prevention Evaluation" (HOPE) trial? | 9541 patients at least 55 years old with history of vascular disease or diabetes and at least one other risk factor randomized in a double-blind manner to ACE inhibitor (ramipril) or placebo for 4–6 years with primary outcome of combined rate of cardiovascular death, MI, or ischemic stroke:<br>At the end of 4 years, primary endpoint was 22% lower in ramipril group than placebo group |

# Chapter 5
# Taking Call

**Chris Molloy and Junjian Huang**

The "call" experience will vary and is based on the institution and the attending physician. In most institutions, "call" means covering the service after-hours and on weekends. The subintern may hold the call pager and answer any immediate questions or see consults. It helps to understand what is a medically emergent case, because in many institutions the rest of the call team (nurse, scrub tech, etc.) will not be activated and the procedure will not be performed unless the case is a medical emergency. The individual taking call should be comfortable with routine postoperative care, management of pain and complications, as well as handling emergent consults in the fields of trauma, emergent ischemia and hemorrhage, thromboembolic disease, as well as infection.

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| Describe how to obtain and calculate ankle-brachial index (ABI)? | Position the patient in the supine position. Measure the bilateral brachial blood pressures and measure the bilateral ankle blood pressures. Calculate the highest brachial pressure divided by the ankle blood pressure to determine the ABI |
| How is the ABI interpreted and what ranges are abnormal? | ABI range<br>0.9 – 1.2: Normal range<br>0.8 – < 0.9: Mild arterial disease<br>0.5 – < 0.8: Moderate arterial disease<br>< 0.5: Severe arterial disease |
| How do you explain normal or elevated ABIs in a diabetic patient with vascular claudication? | In diabetics, the ABI may be spuriously elevated due to medial calcific sclerosis (Mönckeberg sclerosis). In this scenario, toe-brachial index (TBI) and toe pressures are more reliable measures of arterial perfusion. |
| What is the National Institutes of Health Stroke Scale (NIHSS)? | |

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| 1a. Level of consciousness | 0 = Alert; keenly responsive<br>1 = Not alert, but arousable by minor stimulation<br>2 = Not alert; requires repeated stimulation<br>3 = Unresponsive or responds only with reflex |
| 1b. Level of consciousness questions: | 0 = Both answers correct |
| What is the month?<br>What is your age? | 1 = Answers 1 question correctly<br>2 = Answers 2 questions correctly |
| 1c. Level of consciousness commands: | 0 = Performs both tasks correctly |
| Open and close your eyes<br>Grip and release your hand | 1 = Performs 1 task correctly<br>2 = Performs neither task correctly |
| 2. Best gaze | 0 = Normal<br>1 = Partial gaze palsy<br>2 = Forced deviation |
| 3. Visual | 0 = No visual loss<br>1 = Partial hemianopia<br>2 = Complete hemianopia<br>3 = Bilateral hemianopia |
| 4. Facial palsy | 0 = Normal symmetric movements<br>1 = Minor paralysis<br>2 = Partial paralysis<br>3 = Complete paralysis of 1 or both sides |
| 5. Motor arm<br>5a. Left arm<br>5b. Right arm | 0 = No drift<br>1 = Drift<br>2 = Some effort against gravity<br>3 = No effort against gravity; limb falls<br>4 = No movement |
| 6. Motor leg<br>6a. Left leg<br>6b. Right leg | 0 = No drift<br>1 = Drift<br>2 = Some effort against gravity<br>3 = No effort against gravity<br>4 = No movement |
| 7. Limb ataxia | 0 = Absent<br>1 = Present in 1 limb<br>2 = Present in 2 limbs |
| 8. Sensory | 0 = Normal; no sensory loss<br>1 = Mild-to-moderate sensory loss<br>2 = Severe to total sensory loss |
| 9. Best language | 0 = No aphasia; normal<br>1 = Mild to moderate aphasia<br>2 = Severe aphasia<br>3 = Mute, global aphasia |
| 10. Dysarthria | 0 = Normal<br>1 = Mild to moderate dysarthria<br>2 = Severe dysarthria |
| 11. Extinction and inattention | 0 = No abnormality<br>1 = Visual, tactile, auditory, spatial, or personal inattention<br>2 = Profound hemi-inattention or extinction |
| Total score = 0-42 | |

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| What diagnosis should be considered if you see the "floating viscera sign"? | Acute aortic dissection |
| What are the acute aortic syndromes? | 1. Acute aortic dissection<br>2. Intramural hematoma<br>3. Penetrating atherosclerotic ulcer |
| What are the predictors of mortality in patients with aortic intramural hematoma? | Ascending aorta diameter > 5 cm<br>Hematoma diameter > 2 cm<br>Pericardial effusion |
| What types of trauma cases may be IR-related emergencies? | Acute hemorrhage (often visceral bleed or pelvic trauma). Bilateral selective arteriograms in the internal iliac arteries with multiple obliquities are necessary to clear the pelvis. |
| What kidney cases are considered IR emergencies requiring urgent intervention? | Pyonephrosis, acute urinary obstruction, Page kidney |
| What are the indications for percutaneous nephrostomy? | To relieve obstruction, create urinary diversion, pyonephrosis, to establish access for other genitourinary procedures |
| What lung/pulmonary cases are considered IR emergencies requiring urgent intervention? | Massive or submassive PE, massive hemoptysis |

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| What Rutherford classifications of acute limb require immediate intervention? | Class IIb requires immediate intervention for limb salvage. Classes I and IIa are salvageable with urgent intervention. |
| What are the sonographic findings of arterial pseudoaneurysm? | "Yin-yang" sign on color Doppler<br>To-and-fro flow within the pseudoaneurysm neck on Doppler waveform |
| What are the sonographic findings of acute deep vein thrombosis? | Non-compressible veins<br>Echogenic thrombus visualized within the deep vein lumen<br>Absence of color flow within the vein lumen<br>Absence of respiratory phasicity suggests a more central venous obstruction, and further evaluation with CT venogram or MR venogram is warranted |
| What IR procedure is usually performed for massive hemoptysis? | Bronchial artery embolization |
| Where do the bronchial arteries usually originate from? Where can the bronchial artery originate from in normal anatomic variants? | The left bronchial arteries (typically two) usually originate directly from the descending aorta. The right bronchial artery (typically one) arises from a right posterior intercostal or left bronchial artery. They can also originate from internal mammary and subclavian arteries. |
| What is the corona mortis? | Named the "crown of death," an anatomic variant artery, which connects the obturator artery via the external iliac artery. It may be injured during pelvic trauma and surgery or may cause type 2 endoleak. |

# Chapter 6
# Pre-procedure

**Chris Molloy and Junjian Huang**

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| According to SIR guidelines, how is procedural bleeding risk stratified? | The below 2019 updates to periprocedural bleeding risk and recommendations should be reviewed prior to the IR rotation:<br>Society of Interventional Radiology Consensus Guidelines for the Periprocedural Management of Thrombotic and Bleeding Risk in Patients Undergoing Percutaneous Image-Guided Interventions—Part I: Review of Anticoagulation Agents and Clinical Considerations<br>Society of Interventional Radiology Consensus Guidelines for the Periprocedural Management of Thrombotic and Bleeding Risk in Patients Undergoing Percutaneous Image-Guided Interventions—Part II: Recommendations |

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| What value should a patient's INR be prior to a high bleeding risk procedure? | INR ≤1.5 prior to a high-risk procedure |
| What value should the patient's platelets be prior to a high bleeding risk procedure? | Platelets ≥50,000/μL: if platelets ≤50,000/μL, transfuse prior to a high-risk procedure |
| Some patients refuse transfusion of blood products due to religious preferences. What adjunctive medications may be considered to improve hemoglobin levels and decrease bleeding in patients who refuse blood transfusions? | Erythropoietin and desmopressin |
| What agent can be administered to improve platelet function in patients with uremic platelet dysfunction? At what dose? | Desmopressin. Dose 0.3 μg/kg is given intravenously |
| What lab is used to monitor low molecular weight heparin therapy? | Anti-factor Xa activity |

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| How long should LMWH be held prior to a procedure considered high bleeding risk? | Hold LMWH for 24 h or usually 2 doses prior to high-risk procedures |
| What is the minimum number of unique patient identifiers that should be used during the pre-procedural timeout? | Though variable between institutions, generally two unique identifiers should be used during the pre-procedural timeout, for example, the MRN and date of birth |

# Part II
# Vascular Site

# Chapter 7
# Patient Preparation

**Matthew Czar Taon**

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| In patients undergoing procedures with a high risk of bleeding, how long should clopidogrel and aspirin be withheld prior to procedure? | According to the 2019 Society of Interventional Radiology Consensus Guidelines for the Periprocedural Management of Thrombotic and Bleeding Risk in Patients Undergoing Percutaneous Image-Guided Interventions, in procedures associated with a low risk of bleeding, clopidogrel does not need to be withheld. In procedures associated with a high risk of bleeding, clopidogrel should be withheld for 5 days.<br>In procedures associated with a low risk of bleeding, aspirin does not need to be withheld. In procedures associated with a high risk of bleeding, aspirin should be withheld for 3–5 days. |

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| The off-label use of what medication has been shown to reduce bleeding time and complications in uremic patients? | Desmopressin (DDAVP) 0.3 mg/kg. It reaches maximal effect 30–60 min after administration. |
| When administering periprocedural prophylactic antithrombotics for peripheral arterial interventions, what is the recommended method of anticoagulation measurement? | Activated clotting time (ACT) with a point-of-care device.<br>The activated clotting time (ACT) is an assessment of overall coagulation and represents the time it takes the whole blood to clot in the presence of an activator. For many interventional procedures, the patient should be heparinized to maintain an ACT range of approximately 250–300 s.<br>An initiating dose of full-dose unfractionated heparin for therapeutic purposes during interventions can be either empiric or weight based. An empiric dose is a 5000-unit IV bolus followed by a continuous infusion of 1000 units/hour IV. A weight-based dosing regimen with a bolus of 70–100 units/kg, followed by a continuous 18-unit/kg/hour infusion, was found to be more effective in preventing recurrent thromboembolism when compared with non-weight-based regimens.<br>For heparin reversal at the end of the procedure, 1 mg of protamine will neutralize approximately 100 units of heparin. |

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| In a "dirty" procedure that involves entering an infected purulent site, a clinically infected biliary or genitourinary site, or a perforated viscus, how long should antibiotics be administered? | Prophylactic antibiotics should be administered 1 h prior to procedure and continued for at least 48 h post-procedure. |

## Consent

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| The ALARA (as low as reasonably achievable) principle focuses on which three basic radiation protective measures? | Minimizing time, maximizing distance, and using shielding. |
| What is the maximum effective radiation dose for exposed radiation workers in a 1-year and consecutive 5-year period? | Maximum effective dose for an exposed radiation worker in any single year is 50 mSv. Maximum effective dose for an exposed radiation worker in a consecutive 5-year period is 100 mSv. |
| What is the principle of using carbon dioxide (CO2) as a contrast agent for angiography? | CO2 gas displaces the blood and produces a negative contrast for digital subtraction imaging. |
| What medication can be used to reverse the sedation effects of benzodiazepines? | Flumazenil with an initial dose of 0.2 mg IV administered over 15 s to 1 min. Repeat dosing may be necessary since the half-life of flumazenil is shorter than that of most benzodiazepines. |

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| 30-day, 3-month, and 6-month mortality after transjugular intrahepatic portosystemic shunt (TIPS) is significantly increased after what Model for End-Stage Liver Disease (MELD) score? | Patients with MELD > 18 have a significant increase in mortality when compared to patients with MELD less than or equal to 17. The MELD score was initially developed to predict short-term survival after TIPS and was subsequently found to be useful for triaging patients for liver transplantation. Scores ≥ 18 have been found to be associated with 1-month and 3-month mortality of 18% and 35%, respectively. |
| What are the Anesthesia Society of America (ASA) requirements for fasting prior to moderate sedation? | Though variable depending on institution, 6 h fasting for solids and 2 h fasting for liquids. |

## Contrast Allergy Prophylaxis

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| What does the American College of Radiology recommend for contrast allergy prophylaxis? | A combination of 12–13 h of steroids and antihistamine administration. A common regimen includes 50-mg prednisone 13, 7, and 1 h before contrast administration and 50-mg Benadryl 1 h prior to contrast administration. |

# Chapter 8
# Running the Table

**Matthew Czar Taon**

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| The number of viable airborne bacteria in a surgical suite is directly proportional to what aspect of the operating room? | The number of persons present in the operating room. This underscores the importance of limiting traffic flow through the angiography suite only to necessary tasks. |
| According to consensus, what is the recommended time frame between preparation of the sterile instrument back table and the use of the back table? | The recommended time frame is less than 1 h, preferably immediately before the procedure. |
| What is considered the most important step in reducing the spread of infection? | Hand hygiene |

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| When performing a procedure that involves catheter insertion, how long should a sterile drape be? | The Centers for Disease Control and Prevention (CDC) recommends that a sterile drape should be large enough to cover the entire patient and any hardware attached to the operating table. |
| Regarding pre-procedural skin preparation, if a patient is sensitive to chlorhexidine and povidone-iodine solution, what solution can be used to cleanse the skin? | 70% alcohol |
| When injecting contents from a syringe into a catheter, how should the syringe be prepared and what position should the syringe be held? | Every syringe on the table should be labeled and, when injecting, should be held upright to ensure that any air will travel toward the syringe plunger, away from the catheter. |
| When preparing contrast syringes for a procedure, what is an effective method for reducing iodinated contrast dose? | Diluting contrast into a 1:1 contrast to saline ratio. In extremities, a 1:3–1:5 contrast to saline dilution ratio can be enough to provide diagnostic images. In the abdomen, a 1:2 contrast to saline dilution ratio can be enough to provide diagnostic images if the patient is able to hold respiration adequately and if they are of the correct body habitus. |

# Chapter 9
# Choice of Access

**Matthew Czar Taon**

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| How does real-time ultrasound-guided vascular access compare to the use of anatomic landmarks or vessel palpation in terms of success rate, time to access, and complication rates? | Real-time ultrasound-guided vascular access provides active visualization of the target, access vessel, as well as visualization and avoidance of surrounding, vital structures. |
| What Barbeau test waveform is considered a contraindication to radial artery access? | Type D Barbeau waveform. This waveform appears as a flat line on the pulse oximeter and persists beyond 2 min, indicating no collateral supply from the ulnar artery to the radial side of the hand. |

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| Prior to transradial artery interventions, a combination of what medications can be mixed and prepared to be infused through the access sheath in an attempt to prevent radial artery occlusion and spasm? | Nitroglycerin 200 mcg, verapamil 2.5 mg, and heparin 2500 units |
| Where is the optimal access of the common femoral artery (CFA)? | The common femoral artery should be accessed at the level of the femoral head. Access above the femoral head risks retroperitoneal hemorrhage, and access below the femoral head risks thigh hematoma/pseudoaneurysm. |
| What are methods to differentiate a vein versus artery on ultrasound? | Arteries demonstrate pulsatility. Veins demonstrate compressibility. Veins have valves. The common carotid artery is located medial to the internal jugular vein. The common femoral artery is located lateral to the common femoral vein. Assess the direction of Doppler flow. |
| What is a proposed benefit to ipsilateral, antegrade access of the common femoral artery (CFA) to treat infrainguinal arterial disease? | Ipsilateral, antegrade access provides a short working length, which can improve steerability and pushability of wires and catheters. Also, this technique avoids aortoiliac crossover, which can be challenging if there is a steep iliac bifurcation, tortuous or stenotic iliac arteries, or presence of an aortoiliac endoprosthesis. |

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| When accessing a thrombosed hemodialysis fistula or graft, why is it important to ensure that the antegrade and retrograde sheaths face each other but do not overlap? | Thrombus within the segment of overlapping sheath tips would be inaccessible to catheter thrombectomy. |
| In patients with underlying left bundle branch block, central venous catheterization may result in what lethal dysrhythmia? | Central venous catheterization may result in transient right bundle branch block. In a patient with pre-existing left bundle branch block, this may result in life-threatening complete heart block. Techniques to mitigate risks include using a guidewire marked at every 10 cm, to facilitate more careful guidewire manipulation and preparing a noninvasive transcutaneous pacemaker at bedside for patients with known left bundle branch block. If transcutaneous pacing is not successful, a transvenous pacemaker may be necessary. If the iatrogenic injury leads to a persistent third-degree AV block, permanent pacemaker placement should be considered. |
| What are the three endovascular methods to access and treat type II endoleaks? | Transarterial embolization of the inflow and outflow arteries supplying and draining the endoleak, translumbar direct percutaneous puncture of the aneurysm sac with embolization, and transcaval puncture of the aneurysm sac with embolization |

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| Pedal access should be avoided in which type of patients? | Claudicants with single vessel runoff, since pedal access can compromise the only remaining arterial supply to the foot |
| What are the relative contraindications to using vascular access closure devices? | Vascular access above the inguinal ligament, small (<5 mm) vessel size, large arteriotomy size unless a pre-close technique is performed, severe atherosclerosis, need for repeat arterial access, and allergy to a device component |

# Chapter 10
# Seldinger Technique

**Matthew Czar Taon**

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| Describe the Seldinger technique. | Obtain vascular access with a trocar needle, insert soft curved tip guidewire, secure guidewire and remove trocar needle, exchange a sheath/cannula/catheter over the guidewire into the lumen or cavity, and withdraw guidewire. Seldinger described this technique as "needle in, wire in, needle off, catheter on wire, catheter in, catheter advance, wire off." |
| What are potential complications associated with the Seldinger technique? | Failed access, hemorrhage, infection, air embolus, guidewire embolus, injury to adjacent tissue, and pseudoaneurysm formation |
| What units are percutaneous needle diameters measured in? | Gauge; increasing gauge numbers denote decreasing wire diameters. In general, an 18-gauge needle accepts a 0.035–0.038-inch guidewire, and a 21-gauge needle accepts a 0.018–0.021-inch guidewire. |

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| What units are catheter inner diameters measured in? | Inches. This correlates with the units of wire diameters. |
| What units are wire diameters measured in? | Inches |
| What are the units of catheter length? | Centimeters |
| Sheath French sizes refer to what measurement? | Inner diameter. Select sheath size based on the goal of the procedure and what interventional device (balloon or stent) will be used. |
| The outer diameter of a sheath is how much bigger than its inner diameter? | Sheath outer diameter, and therefore size of arteriotomy or venotomy is 1.5–2-French sizes bigger than that of its inner diameter. |

# Chapter 11
# Guidewires

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| What are the four major components of a guidewire? | Core, tip, body, and coating. Guidewires can be made of various materials including stainless steel, nitinol, platinum, or other alloy metals. The core of a guidewire, referred to as a mandrel, is composed of a stiff, inner, central wire upon which subsequent layers are wound. The shaft of wires can have different degrees of stiffness and facilitates structural integrity during wire use. The stiffness of the shaft is primarily attributed to the metal type and thickness of the core.<br>The distal end of the guidewire is referred to as the tip. If the core extends up to the tip of the wire, it is referred to as a "core-to-tip" design, which provides good tactile feedback, tip control, tip load, and torqueability. If the core does not reach the distal tip of the wire, a small, flat metal ribbon provides the continuity to the distal most tip, and is referred to as a "shaping ribbon" design. This design provides good wire shape retention, softness, and flexibility of the tip, but with decreased tip torque control. Historically, guidewire designs incorporated a fine "safety wire" along the full length of the wire to prevent the outer wire coil from uncoiling and breaking off. This precursor to the safety ribbon design allowed the wire to be shaped but resulted in added tip stiffness. Some wire tips lack a shaping ribbon altogether resulting in greater wire flexibility and safety but with decreased directional control.<br>The body of a guidewire includes coils, covers, and sleeves. The body of the guidewire, surrounding the core, is typically made of coils or polymer (plastic) covering. If a guidewire consists of a polymer cover along the body but leaves the distal free coils along the tip uncovered, this is referred to as a sleeve. The spring coil design contributes to a wire's shapeability, shape retention, and tactile feedback. A polymer cover design can improve guidewire deliverability but may decrease tactile feedback.<br>The body of the wire, whether it be a spring coil or polymer cover design, can have an additional coating. This additional coating can reduce surface friction, improve tactile feedback, and improve guidewire tracking. Hydrophilic coating attracts water to create a slippery "gel-like" surface for improved trackability. Alternatively, hydrophobic coating repels water to create a "waxlike" surface which enhances tactile feedback but decreases slipperiness and trackability. |

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| What is the relationship between columnar strength (stiffness) of a wire, torsional strength, and radius of the wire? | Both the stiffness and torsional strength of a guidewire are directly proportional to the fourth power of the core diameter. |
| What are the two factors of guidewires that determine frictional resistance? | Guidewire stiffness and the coefficient of friction |

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| What is the relationship between lubricity of a guidewire and tactile feedback? | Inverse relationship. As lubricity increases, tactile feedback decreases. |
| What is tip load? | Tip load is the measure of how many grams of force (gram-force) are required to buckle a wire tip when forced against a standard surface. |
| What is penetration power? | Penetration power is calculated as wire tip load divided by wire tip area. Tapered tip wires have higher penetration power as compared to non-tapered wires, even if tip load is equivalent, given the decreased wire tip area. Also, penetration power can be increased for any wire if there is an over-the-wire device in place, such as a microcatheter, with minimal wire protrusion. |
| How does a long core-to-tip taper compare to a short core-to-tip taper in terms of support and trackability? | Wires with a long core-to-tip taper provide improved vessel tracking but less support. Wires with a short core-to-tip taper provide more support but greater tendency to prolapse. |

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| What is the difference between hydrophilic and hydrophobic wire coatings? | Hydrophilic coatings attract water to create a "gel-like," lubricious wire surface. Given the ease of advancement, these carry a risk of dissection or perforation. Hydrophobic coatings repel water to create a "waxlike" wire surface with improved tactile feedback but decreased lubricity and trackability. |
| How long should an exchange wire be in relation to the length of the catheter being utilized? | Ideally, an exchange wire should be two times the length of the catheter to maintain wire positioning during catheter exchange. |
| What is the SAFARI technique? | SAFARI refers to subintimal arterial flossing with antegrade-retrograde intervention. It involves obtaining through-and-through wire access in the subintimal space to cross a chronic total lower extremity arterial occlusion. |

# Chapter 12
# Catheters

**Matthew Czar Taon**

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| What is the difference between a nonselective (flush) catheter and a selective catheter? | Nonselective flush catheters are designed to withstand high injection pressures and provide high-flow rate contrast injections with uniform contrast dispersal and minimal recoil. Selective catheters are designed to provide improved torqueability, facilitate cannulation of a vessel orifice, and obtain distal access. A guiding catheter is a type of selective catheter and is constructed to have a larger inner diameter to assist in delivering and stabilizing interventional devices. |
| Generally, what are the three layers of a guiding catheter? | An outer layer composed of polyurethane or polyethylene to provide stiffness, a middle layer composed of a wire matrix for torque generation, and a lubricious inner coating made of polytetrafluoroethylene (PTFE) to allow for smooth passage of balloon catheters and stents. |

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| What are the three basic components of a guiding catheter? | A hub for connection; a shaft with varying diameter, length, and stiffness; and a soft tip |
| What is one method to determine if a catheter tip is facing anterior or posterior? | The catheter tip is facing the anterior position if it turns right with clockwise rotation and left with counterclockwise rotation. The catheter is facing the posterior position if it turns left with clockwise rotation and right with counterclockwise rotation. |
| What is the difference between passive and active support methods to keep a guiding catheter in position and to provide a stable platform? | Passive support is dependent on the inherent physical characteristics of the guide catheter wall and the preformed shape of the catheter. Minimal manipulation of the catheter is required. Active support requires operator-dependent catheter manipulation to seat a catheter beyond the ostium of a vessel or mold the catheter within the endovascular space to obtain stable position. |
| What is the double flush technique? | For catheters at or above the thoracic aorta, a double flush technique is used to prevent migration of blood clots into the cerebral circulation. This technique requires two syringes: one is utilized to aspirate the catheter with subsequent disposal of the contents, while the other syringe is utilized to flush the catheter. |
| What are the characteristics of a braided catheter? | Braided catheters have increased axial rigidity, have improved stability, are less vulnerable to kinking or rupture, but have less ability to be steam shaped. |
| In general, why must a catheter be advanced over a wire? | To prevent the catheter tip from scraping the vessel wall and causing dissection or emboli |

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| What is a method to prevent inadvertent air embolus from occurring during guidewire removal from a catheter? | Remove the guidewire slowly and drip/inject heparinized saline into the catheter hub during wire withdrawal. |
| What is the difference between a rapid exchange (monorail) system compared to an over-the-wire system? | With a rapid exchange (monorail) system, the guidewire exits the catheter relatively close to the tip of the catheter, allowing the use of shorter wire lengths and smaller wire, catheter, and interventional device diameters. With an over-the-wire (OTW) system, the guidewire passes through the entire length of the catheter lumen in a coaxial fashion. |

# Chapter 13
# Connectors

**Matthew Czar Taon**

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| What are examples of flow-control devices? | Flow switches, metal or plastic stopcocks, K-switch valves used for CO2 angiography, and rotating hemostatic valves |
| What is the difference between a Luer-lock and a Luer-slip connection? | A Luer-lock tip has a collar with an internal thread and requires twisting and locking of the connection tip. It is used for injections requiring a secure connection. A Luer-slip tip is composed of a smooth spigot without a collar. It requires a friction-fit connection utilizing push-and-twist technique. Luer-slip tips are used for rapid refilling or for tasks involving multiple adapters. |

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| What are the parts of a Tuohy-Borst rotating hemostatic valve? | A rotating Luer-lock male connector tip, an angled female Luer-lock connection for continuous flush, and a valve which allows placement of additional catheters or wires while preventing backflow of saline flush or blood |
| If an air embolus is suspected in a patient with a rotating hemostatic valve and saline flush, what can be done to prevent further embolization? | Stop the flush immediately to prevent additional forward flow of fluid and air emboli. Open the rotating hemostatic valve and allow backflow of the blood and air embolus. Immediately place the patient left side down or head down. Air emboli will float to the least dependent position. The Trendelenburg position keeps a left-ventricular air embolus away from the coronary artery ostia to prevent the occlusion of coronary arteries. Left lateral decubitus positioning helps to trap air emboli in the nondependent segment of the right ventricle to prevent flowing into the pulmonary arteries. The left lateral decubitus position may also prevent air emboli from passing through a patent foramen ovale into the left ventricle where it could embolize to distal arteries, including intracranial arteries. |
| When utilizing a coaxial catheter combination with an outer guiding catheter and smaller inner catheter/ microcatheter, why is it recommended to connect an extra flush system to the outer guiding catheter? | Avoid thrombus from forming between the outer catheter and inner catheter |

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| When deploying a detachable coil, why is it important to advance the long plastic introducer completely into the catheter hub before advancing the coil? | To prevent the coil from deploying within the hub of the catheter |
| What is a problem that oil-based contrast agents such as Ethiodol (Lipiodol) can cause when using connectors, catheter hubs, syringes, or three-way stopcocks made of soft plastics? | Oil-based contrast agents such as Ethiodol (Lipiodol) can dissolve or crack certain types of plastics and rubber stoppers. Materials made of polycarbonate are more susceptible to damage by Ethiodol. Metal, glass, polypropylene, polyamide, and polysulfone materials provide more durable connections when using oil-based contrast agents. |
| When preparing a heparinized saline flush bag and tubing, what is one of the most important steps? | Clear air from the bag and tubing prior to procedure to prevent air embolus. |
| What kind of tubing should be used with power injection pumps? | Noncompliant pressure tubing. These are designed for high pressures and high flow rates. Low-pressure connection tubing is more compliant and may burst if used with a power injector. |

# Chapter 14
# Balloons

**Matthew Czar Taon**

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| How is an angioplasty balloon prepped? | Method 1: Attach a 50-mL syringe filled with one-half (or one-third dilute contrast to the angioplasty balloon hub). Aspirate the syringe to create a vacuum. Upon release of the syringe plunger, contrast will replace the air within the balloon lumen. Repeat several times to maximize air reduction. Lastly, replace the syringe with an inflation device containing the same contrast dilution, via a wet-to-wet connection.<br>Method 2: A balloon can also be prepped using a three-way stopcock. Attach an inflation device containing dilute contrast to a three-way stopcock, and open the stopcock to aspirate the balloon lumen. The resulting vacuum draws contrast from the inflation device into the balloon lumen, replacing the air within the balloon lumen. Rotate the stopcock to the open port and expel excess air from the inflation device. Repeat this process several times to maximize air reduction. Air within the balloon lumen must be completely replaced with contrast to ensure that the entire balloon lumen can be visualized. Air bubbles can obscure the image and hide a stenosis. |

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| What is the nominal pressure? | Nominal pressure is the amount of pressure, in atmospheres (atms), required to inflate the balloon to its labeled diameter. |
| What is the rated burst pressure? | The pressure level, in atmospheres (atms), a balloon can expand to without rupture. The rated burst pressure is based in vitro testing. Generally, at least 99.9% of the balloons (with 95% confidence) will not burst at or below their rated burst pressure. |
| What is the working range of a balloon catheter? | Working range is the inflation range between nominal and rated burst pressure. |
| What is the working length of a balloon catheter? | The surface of the balloon that contacts the vessel wall when inflated |
| What is the mechanism of plain old balloon angioplasty (POBA) to treat an arterial atherosclerotic stenosis? | Plaque fracture, vessel stretching, and lumen expansion. Essentially, plain balloon angioplasty creates controlled vessel wall ripping of the intima and some of media. |
| What are the types of wall stresses involved with balloon angioplasty? | Torsional stress, radial stress, and longitudinal stress. Torsional stress is imparted on the vessel wall through a twisting motion when a balloon unfolds during inflation. Radial stress is imparted outwardly on the vessel wall as a balloon unfolds. Longitudinal stress elongates the vessel wall during balloon inflation. |

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| What is the relationship between vessel injury and the rate of vessel wall stretching? | There is a direct relationship between vessel injury and the rate at which the vessel wall is stretched. Slow, low-pressure inflations tend to minimize trauma. |
| What are the two components of a drug-coated balloon matrix coating? | Antiproliferative drug and drug-transferring excipient. Antiproliferative drugs include paclitaxel and sirolimus which reduce in-stent restenosis. Excipients, such as urea and shellac, are polymers that create a matrix which functions to both retain the drug on the balloon surface and transfer it to the vascular endothelium. The molecular characteristics of the excipient influence the adhesion and diffusion of drugs into the vascular endothelium. |
| What are the complications associated with balloon angioplasty? | Flow-limiting dissection, vessel rupture, elastic recoil, and restenosis |

# Chapter 15
# Stents

**Matthew Czar Taon**

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| What characteristics differentiate a balloon-expandable stent from a self-expanding stent? | Balloon-expandable stents demonstrate increased radial strength and more predictable placement but are generally less flexible compared to self-expanding stents. Balloon-expandable stents are not recommended at flexion points due to risk of stent collapse. Self-expanding stents are highly flexible, can be placed at flexion points due to their ability to re-expand, but have a less predictable deployment compared to balloon-expandable stents. Additional balloon angioplasty may be performed after a self-expandable stent is deployed to obtain better vessel wall apposition. |

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| What characteristics differentiate a covered stent from a non-covered stent? | A covered stent (stent graft) is a metal stent lined with polytetrafluoroethylene (PTFE) or Dacron. They can be available in self-expanding or balloon-expandable platforms. Generally, covered stents require a larger sheath size compared to non-covered stents. Covered stents can completely exclude plaque and thrombus. |
| How does intravascular ultrasound (IVUS) compare to contrast angiography in terms of sizing vessel diameters? | IVUS is superior to angiography for sizing vessel diameters since it provides a two-dimensional axial view of the vessel lumen and vessel wall. In addition to sizing, IVUS can offer much valuable information, including plaque characterization, whether or not atherectomy should be performed prior to balloon angioplasty or stent placement, and after stent deployment to assess for appropriate wall apposition and plaque coverage. |
| In failing dialysis-access grafts, how does the use of covered stent grafts compare to balloon angioplasty in terms of patency? | Use of a stent graft is associated with longer patency and freedom from repeat interventions compared to standard balloon angioplasty. |
| What is the mechanism of action of drug-eluting stents to treat peripheral arterial disease? | Drug-eluting stents work mechanically to treat elastic recoil and dissection and molecularly via the antiproliferative drug, paclitaxel, to mitigate peripheral arterial disease progression, injury response, foreign body reaction, and in-stent restenosis. |

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| What are the factors that can make venous stenting more challenging? | Venous vessel walls are very thin.<br>Veins are inherently compressible.<br>Venous flow is much slower than arterial flow.<br>Veins contain valves.<br>No accurate noninvasive or invasive test is available to evaluate the hemodynamic significance of venous outflow obstruction.<br>The degree of venous stenosis that is hemodynamically critical is unknown. |

# Chapter 16
# Embolization

**Matthew Czar Taon**

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| What are the two general classifications of embolic agents? | Temporary agents which include autologous blood clot and Gelfoam. Permanent agents which include coils and vascular plugs, particulates, and liquid (alcohol, sodium tetradecyl sulfate (Sotradecol), cyanoacrylate, and ethylene vinyl alcohol (Onyx)). |
| What are the three important aspects to evaluate when choosing an appropriate embolic agent? | Assess the size of the vessel/vascular bed to be embolized. Determine whether the goal is temporary or permanent occlusion. Determine whether the embolized tissue should remain viable after embolization. |

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| Prior to administering NBCA (n-butyl-2-cyanoacrylate) glue for embolization, what solution should be flushed through the microcatheter to prevent the glue from prematurely solidifying upon contact with an ionic solution? | 5% dextrose solution. This nonionic solution is used instead of an ionic saline flush to prevent polymerization of the NBCA mixture on contact with residual blood or saline in the catheter tip. Furthermore, injecting dextrose creates a local nonionic environment at the catheter tip which enables more distal NBCA progression. |
| Prior to administering ethylene vinyl alcohol (Onyx) for embolization, what solvent should be flushed through the catheter to prevent precipitation within the lumen of the microcatheter? | Dimethyl sulfoxide (DMSO). Onyx is an ethylene vinyl alcohol copolymer dissolved in the organic solvent dimethyl sulfoxide (DMSO) opacified with tantalum powder. Once it comes into contact with an ionic solution, such as blood, the DMSO dissipates and the Onyx solidifies into a spongy, cohesive embolic material. |
| Prior to preparing a catheter with DMSO, what aspect of the catheter should be verified? | The microcatheter must be DMSO compatible. DMSO can break down many plastic materials. |
| What is the relationship between embolic agent size and likelihood of organ ischemia? | In general, the smaller the embolic agent, the greater the likelihood of organ ischemia. Smaller embolic agents are able to flow more distally into arterioles and capillary beds, thereby increasing risk of necrosis. The larger the particle size, the less likely the risk of ischemia given the presence of collateral arterial flow. |

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| What is nontarget embolization? | Migration of the embolic device or material from the intended target artery into an undesired artery due to reflux or unintended catheter movement. |
| When performing bronchial artery embolization, what are the critical vessels to be aware of? | Any arterial supply to the spinal cord, specifically the anterior spinal artery, since nontarget embolization of the anterior spinal artery can cause paraplegia. |
| What are the most important properties of embolization coils? | Target vessel diameter<br>Configuration (tertiary configuration, loop diameter, and length)<br>Stiffness<br>Volume (packing density) |
| Define coil packing density. | Packing density is defined as the number of coils multiplied by coil volume divided by aneurysm volume. High packing density and low residual aneurysm volume decrease the likelihood of aneurysm recanalization. |

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# Part III
# Vascular Disease

# Chapter 17
# Abdominal Aortic Aneurysms

**Dania Daye**

## Evaluating Patient

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| What are the findings of AAA on physical exam? | Midline palpable pulsatile abdominal mass |
| What is the diameter that is used to define an AAA? | > 3 cm or 1.5x the normal diameter |
| Who should be screened for AAA? | The USPSTF recommends onetime ultrasound screening of men between the ages of 65 and 75 with a smoking history.<br>The USPSTF also recommends selective onetime ultrasound screening of men aged 65–75 based on patient's medical history, family history, and risk factors.<br>The USPSTF states that data is insufficient to recommend AAA screening for women with and without smoking history. |

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| What study is used to screen a patient for AAA and follow the aneurysm size over time? | Ultrasound |
| What study should be ordered if an AAA leak or impending rupture is suspected? | CT with contrast in usually recommended. However, a non-contrast CT can be sufficient if there is concern for contrast-induced nephropathy.<br>Abdominal CT allows differentiating ruptured from non-ruptured aneurysms, allows the identification of the extent of the aneurysms, and provides important anatomic information to determine suitability for endovascular repair. |
| What are the signs of abdominal aortic rupture on CT? | Retroperitoneal hematoma or stranding. Indistinct aortic wall or loss of fat plane between aortic wall and surrounding tissues. The "draped aorta" sign is an inseparable tissue plane between a concave posterior aorta and the adjacent lumbar vertebral body. It is associated with impending or contained rupture. Retroperitoneal fibrosis may also cause loss of tissue plane distinction but often pulls in the ureters medially (aneurysm will push them out) and contributes to upstream hydroureteronephrosis, as well as often narrows the aorta and IVC.<br>Contrast extravasation. |
| What is the presentation triad of a patient with a leaking AAA? | Abdominal pain, hypotension, and pulsatile abdominal mass |

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| What medical therapy may a patient with AAA be on? | Statins: Decrease C-reactive protein (CRP) and matrix metalloproteinase-A (MMP-A)<br>Tetracyclines: Inhibit MMP-9<br>Aneurysms demonstrate decreased growth rates at 6 and 12 months.<br>ACE-I: Decrease risk of rupture<br>ARB: Decrease rate of formation and expansion |

## High Yield History

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| What factors are associated with AAA? | Smoking, increasing age, coronary artery disease, high cholesterol, hypertension, peripheral vascular disease, and family history |
| What are the major complications of AAA? | Rupture and distal embolization |
| What are the risk factors that are associated with AAA rupture? | Large diameter (> 5 cm), recent rapid expansion, poorly controlled hypertension, and COPD |
| What is the most common etiology of AAA? | Atherosclerosis. AAA is the result of a combination of inflammation, smooth muscle cell apoptosis, and extracellular matrix protein degeneration. This ultimately results in subintimal fibrosis and decreased delivery of oxygen and nutrients to the aortic wall. Combined with shear stress of hypertension on the vessel wall and within the adventitial vasa vasorum, gradual wall degeneration and expansion occur. |

## Indications/Contraindications

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| When is an aneurysm repair indicated? | Diameter > 5.5 cm (male) or > 5.0 (female), recent rapid aneurysm expansion (> 5 mm in 6 months or 10 mm per year), patient symptoms, and AAA leak or rupture<br>Earlier repair may be indicated in the presence of the following:<br>Inheritable condition; intervene at diameter > 5.0 cm (male) or > 4.5 (female).<br>Saccular aneurysm.<br>Presence of penetrating atherosclerotic ulcer.<br>Presence of pseudoaneurysm.<br>Presence of thrombotic or embolic complications.<br>Signs or symptoms of infection or inflammation.<br>Presence of coexisting iliac disease. |
| What are the available treatment options for AAA? | Open surgical repair (mortality as high as 7% and morbidity as high as 50% with open elective repair)<br>Patients with cardiac, pulmonary, or renal dysfunction can pose high operative and/or anesthesia risk.<br>EVAR |
| Who are ideal candidates for EVAR? | Those with infrarenal aneurysms. Juxta-renal aneurysm risk graft occlusion of the renal arteries. Juxta-renal AAA is defined as involving the infrarenal abdominal aorta adjacent to or within 1 cm of the lower margin of the renal artery origins. Accessory renal arteries should be identified as coverage may lead to infarction of part of the kidney, and/or lead to a path for future endoleak.<br>Access vessel large enough to accommodate stent graft delivery system (6–8 mm).<br>Non-tortuous vessels.<br>Patients in whom the IMA is not the predominant blood supply to the colon (as may be seen in the setting of significant narrowing of the SMA). |

## Relevant Anatomy

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| What is a unique change of the aortic wall as it descends from the thorax to the abdomen? | The number of collagen layers in the media decreases. The size and number of adventitial vasa vasorum also decrease. |
| What is the pathophysiology of aneurysm formation? | Aneurysm expansion is proportional to the degree of wall stress and inversely proportional to wall thickness. Degenerative thinning of the media is seen. Aneurysmal walls demonstrate decreased number and degraded organization of concentric smooth muscle cells and elastic lamina. Fragmented collagen is also seen. |
| Where are most AAAs located? | 95% of AAA are located below the renal arteries (infrarenal). Up to 40% of AAAs are associated with iliac artery aneurysms, which may require the placement of a bifurcated aortic endograft. |
| What is the definition of a true aneurysm? | Localized dilation of all three layers of a vessel |
| What is the most common shape of an atherosclerotic aneurysm? | Fusiform |
| What is the most common shape of a mycotic aneurysm? | Mycotic aneurysms are most often pseudoaneurysms and saccular in structure. Blood culture is positive 50% of the time (approximately 50% *S. aureus*, frequently salmonella). |
| Can the size of an aortic aneurysm be reliably evaluated by angiography? | No. Large aneurysms often have a mural thrombus. With only the lumen opacified, the outer size of the aneurysm cannot be appropriately evaluated. |

## Relevant Materials

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| What are the types of stent graft that are available? | Straight<br>Tapered<br>Bifurcated<br>Fenestrated<br>Branched |
| What are the general three components of an endoprosthesis device? | A delivery system for graft introduction and deployment<br>A high radial force, self-expanding metallic stent framework<br>Supports and allows for vascular attachment<br>Graft fabric that excludes the aneurysm and serves as a new conduit for blood flow |
| What is the most commonly used device to repair an AAA? | Bifurcated stent graft |
| Which features of the aneurysm neck are suitable for EVAR? | At least 15 mm in length<br>Non-aneurysmal (18–32 mm in diameter with parallel walls)<br>Angled less than 45°<br>Relatively free of major calcification or thrombus |
| What is the recommended diameter of a stent graft? | 10–20% greater than the diameter of the implantation site |
| What is an important anatomic consideration for access when planning endovascular AAA repair? | The common femoral artery, external iliac artery, and common iliac artery diameters should all be measured from inner wall to inner wall on axial CT and should be compatible with accommodating 16–22 Fr introducer sheaths for delivery of endografts. |

## General Step by Step

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| What are the general, overall steps involved with any AAA patient scheduled to undergo EVAR? | Imaging and planning<br>Graft and patient selection<br>The EVAR procedure<br>Post-procedure surveillance<br>Management of EVAR-related complications |
| What is the usual access used in EVAR? | Bilateral common femoral arteries |
| What type of catheter is typically first introduced? | Calibrated/marker pigtail or straight flush catheter |
| Where should the first marker on the catheter be positioned for length measurements? | Lowest renal artery origin |
| Once the stent graft device is introduced over a superstiff wire, where is the superior end of the endograft positioned? | At the level of the lowest renal artery |
| When placing a bifurcated stent graft, what is the purpose of performing a retrograde angiogram at the bottom of the graft limbs? | Preserve hypogastric artery flow.<br>Limbs should terminate within 1 cm of the hypogastric artery.<br>If a suitable distal landing zone is not present in the common iliac artery, limbs may need to be extended into the external iliac artery, which may require embolization of one or both hypogastric arteries. |
| What should you look for on the final angiogram? | Aneurysm exclusion without presence endoleaks. Normal perfusion of kidneys and lower extremities. |

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| What is the postoperative management following EVAR? | Admit overnight: Analgesia, IV fluids, diet, monitor access, CPR status, ambulation ability, and overall postoperative state.<br>Medical management should be in line with management of coronary artery disease. |

## Complications

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| What is an endoleak? | Residual blood flow in the aneurysm sac |
| How do you assess for endoleaks? | CTA, MRA, or US. Contrast-enhanced ultrasound is an emerging, cost-effective modality, which may be used to assess for endoleak. |
| What are the five types of endoleaks? | Type I: leak at endograft ends due to an inadequate seal<br>Type II: aneurysm sac filling via a branch vessel<br>Type III: leak through a defect in the graft fabric or junctional separation of modular components<br>Type IV: porous graft<br>Type V: endotension (the continued expansion of the aneurysm sac without radiographic evidence of a leak site) |
| What is the most common type of endoleak? | Type II: collateral vessels leading to residual flow into aneurysm sac.<br>Treatment is considered somewhat controversial, though some accepted indications for treatment include growth of the aneurysm sac by 5 mm or other features that indicate persistent pressurization of the native sac, such as persistent endoleak on follow-up, large feeding or draining artery, and presence of high flow within the aneurysm sac. The most commonly involved feeding arteries are the IMA and lumbar arteries. |

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| In what case can colonic ischemia take place following EVAR? | Occlusion of the IMA by the endograft in a patient who does not have well-developed collaterals |
| What is anterior spinal syndrome? | Paraplegia, loss of pain/temperature sensation, and loss of bladder/bowel control |
| If a patient presents with anterior spinal syndrome after EVAR, which vessel did the endograft occlude? | The artery of Adamkiewicz |
| If a patient has undergone bilateral hypogastric artery embolization to prevent type 2 endoleak, which symptoms may be expected on follow-up? | Erectile dysfunction<br>Buttock claudication<br>Spinal cord, bladder, and colon ischemia<br>This procedure may be staged prior to EVAR in an effort to promote collateral circulation formation and avoid ischemic complications prior to exclusion. |
| What are other possible complications of EVAR? | Aortoenteric fistula<br>Aortovenous fistula<br>Erectile dysfunction<br>Graft infection |
| What are some clinical features of aortoenteric fistula? | More common in the open surgical population (0.6–2.0% annual incidence)<br>Abdominal pain and sepsis<br>Classically a "herald," self-limited bleed followed by catastrophic bleeding<br>Nearly always involves the duodenum<br>On cross-sectional imaging, expected peri-graft edema, fluid, and ectopic gas can persist up to 3–4 weeks. Persistence beyond this period of time should raise suspicion for infection. Look for loss of fat planes between graft and bowel. |

## Landmark Research

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| According to recent studies, what are the main advantages of EVAR compared to open repair? | Lower blood loss<br>Fewer days in hospital post-procedure<br>Lower complication rates<br>Decreased in-hospital and 30-day mortality |
| How does the long-terms mortality differ between EVAR and open surgical repair? | Lower mortality at 4 years with EVAR (4%) compared to open repair (7%), though longer-term mortality rates demonstrate similarity |
| What is the utilization trend of EVAR that has been recently reported in the literature? | EVAR has been progressively replacing open surgical repair for infrarenal AAA repair. |

## Common Questions

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| How does endovascular abdominal aortic aneurysm repair (EVAR) compare to open surgical repair in the early perioperative period? After 2 years? After 8 years? | EVAR demonstrates lower rates of morbidity and mortality when compared with open surgical repair in the early perioperative period (within 30 days post-procedure), equivalent outcomes after 2 years, but higher total mortality and aneurysm-related mortality after 8 years. |
| What is Laplace's law and how does it relate to aneurysms? | The law states that tension (T) equals pressure (P) multiplied by the diameter (D). It states that the larger the radius of the sphere, the greater the wall stress. As the aneurysm enlarges, the greater the stress on the aortic wall increases the risk of rupture. |
| How long is endograft imaging surveillance recommended after EVAR? | Indefinitely |

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| At what time intervals is imaging surveillance performed after EVAR? | Follow-up may be obtained at 1 month and 12 months. A 6-month follow-up may be obtained if there is presence of an endoleak, and then yearly. Key features to be able to identify are any evidence for graft thrombosis, migration, or fracture. |

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# Chapter 18
# Thoracic Aortic Aneurysm Chapter

**Peyton Cramer and Lourdes Alanis**

## Evaluating Patient

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| What is a thoracic aortic aneurysm (TAA)? | Localized dilatation of the thoracic aorta greater than 50% of normal. The upper limit of normal caliber for the descending thoracic aorta is 3–3.5 cm. |
| What are the two major types of aneurysms? | 80% are fusiform (uniform and circumferential) and 20% are saccular (localized outpouching). |
| What chest X-ray findings that should raise suspicion for a thoracic aortic aneurysm? | Widening of the mediastinal silhouette, enlargement of the aortic knob, and tracheal or esophageal deviation |

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| Which imaging modality is most critical for evaluating thoracic aortic aneurysms? | Computed tomography angiography (CTA) from the thoracic inlet to the femoral artery bifurcations. Non-contrast images help visualize calcifications and intramural hematomas, while arterial-phase angiography provides accurate aneurysm measurements. |
| What are additional imaging modalities that can be used to further evaluate thoracic aortic aneurysms? | Magnetic resonance angiography (MRA), transesophageal echo (TEE), and intravascular ultrasound (IVUS) |
| Why is it important to thoroughly assess the femoral and iliac vasculature? | Significant tortuosity, thrombus, or calcification might preclude an endovascular approach. Adequate vessel caliber is essential for accommodating the endograft delivery system. |

## High Yield History

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| What is the prevalence of thoracic aortic aneurysms? | 6–10 per 100,000 |
| What is the average age of diagnosis? | 65 years old, with women presenting approximately 10 years later than men |
| Is there a gender predominance? | Slightly, with a male-to-female ratio of 1.5:1–1:1 |
| What are the risk factors? | Atherosclerosis, aortic dissection, connective tissue disorders, family history, trauma, infection, and vasculitis |

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| Which connective tissue disorders are associated with TAAs? | Marfan syndrome, Ehlers-Danlos syndrome, Loeys-Dietz syndrome, and Turner syndrome |
| What are the symptoms of thoracic aortic aneurysms? | Chest discomfort and surrounding organ compression (new onset hoarseness, dysphagia, dyspnea, hemoptysis) |
| What are the risk factors for aneurysm rupture? | Size > 6 cm, increasing age, and tobacco use |
| What is the most common complaint associated with rupture or impending rupture? | Acute onset of back and/or chest pain |

## Indications/Contraindications

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| What are the methods available for thoracic aortic aneurysm repair? | Aneurysms of the ascending aorta generally require surgical reconstruction, while aneurysms of the descending aorta are addressed with either surgical or endovascular techniques. |
| What does TEVAR stand for? | *T*horacic *e*ndo*v*ascular *a*ortic *r*epair |
| TEVAR is approved to treat which medical conditions? | Aortic aneurysmal disease, type B aortic dissection, traumatic aortic transection, and penetrating atherosclerotic ulcer |
| What are the indications for thoracic aortic aneurysm repair? | 1. Size (greater than 5.5 cm)<br>2. Rapid expansion (greater than 5 mm within 6 months)<br>3. Symptoms |

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| What are the advantages of TEVAR over open surgical repair? | Avoidance of thoracotomy or sternotomy, decreased blood loss, reduced spinal cord ischemia, and shorter hospitalizations |
| What is an endograft "landing zones"? | The landing zones are the sites proximal and distal to the aneurysm where the endograft will "land" during the endovascular repair. In order to ensure stable fixation and adequate seal, there must be 2 cm of healthy, parallel aortic wall both proximal and distal to the aneurysm. |
| How is the landing zone diameter measured? | From inner wall to inner wall, excluding calcifications but including intraluminal thrombi and plaque |
| Is unfavorable anatomy an absolute contraindication to TEVAR? | No, various techniques have been developed to overcome these barriers, such as additional cuffs or fenestrated grafts. |
| Is TEVAR recommended in patients with underlying connective tissue disorders or Takayasu? | No, because the fragile tissue is not suitable for long-term endograft seal. |

## Relevant Anatomy

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| What are the three components of the thoracic aorta? | 1. Ascending aorta<br>2. Aortic arch<br>3. Descending aorta |

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| Where is the most common site of thoracic aortic injury when the body undergoes significant deceleration? | The aortic isthmus is the most common site of origin of aortic dissection. The isthmus is a constriction of the aortic arch just distal to the origin of the left subclavian artery at the site of the ductus arteriosus. |
| Which vessels supply the anterior spinal cord? | The vertebral arteries |
| Which vessels supply the posterior spinal cord? | The posterior inferior cerebellar arteries |
| What is the great radicular artery of Adamkiewicz? | The principal vessel that feeds the lower thoracic, lumbar, and sacral portions of the spinal cord. The vessel most commonly arises between T9 and T12 from a single intercostal artery as the anterior radiculomedullary artery that continues as a hairpin loop, forming the characteristic appearance of the artery of Adamkiewicz. Specifically, the artery arises on the left from the radicular anterior artery of the spinal branch of the posterior intercostal artery. The origin of the artery can occur as high as T6. |
| Which vessel(s) gives rise to the intercostal arteries? | The subclavian arteries provide the first two intercostal arteries and the descending thoracic aorta provides the remaining nine intercostal arteries. |

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## Relevant Materials

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| What are the recommended aortic measurements for stent-graft placement in a descending TAA? | Proximal and distal neck diameter of less than 42 mm is recommended to prevent stent migration.<br>Aneurysm length and total treatment length measurements ensure adequate stent coverage of the aneurysm.<br>Radius of curvature of greater than 35 mm or aortic angulation of less than 60° is recommend to achieve adequate circumferential seal and prevent endoleaks. |
| For descending TAAs, the stent-graft diameter is generally oversized by how much relative to luminal diameter of the landing zones? | 10–20% to select the most correct diameter of the endoprosthesis and to ensure a tight circumferential seal and secure anchoring to prevent migration |
| An access vessel of what size is necessary for a standard 24 Fr delivery device? | A vessel of at least 8 mm in diameter given 1 Fr is equal to 0.33 mm diameter, and therefore, 24 Fr is equal to 8 mm diameter. In calcified vessels, open surgical cutdown is preferred. |

## General Step by Step

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| Why should arterial pressure be continuously monitored during the thoracic stent-graft placement? | In addition to continuous monitoring of vital signs, arterial pressure should be closely monitored to avoid hypotension and decrease the risk of spinal cord ischemia. |

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| What can be used to detect neurologic complications? | Intraoperative somatosensory-evoked potentials (SSEP) and motor-evoked potentials (MEP) help monitor spinal cord function to prevent injury and allow for early treatment if detected. Intervention includes draining CSF if CSF pressure becomes elevated and ensuring adequate spinal cord blood flow by maintaining a minimum distal arterial pressure of 60 mmHg. |
| What should the achieved activated clotting time be in heparinized patients? | Patients should be anticoagulated throughout the procedure to achieve an activated clotting time of 250–300 s to reduce thromboembolic complications. However, increased activated clotting times > 300 s may increase bleeding complications. Protamine is given for reversal of heparin anticoagulation. Most serious reaction to protamine is anaphylaxis, characterized by circulatory shock, severe bronchospasm, and occasionally cardiac arrest. |
| What is the preferred arterial access for thoracic stent-graft placement? | Common femoral artery (external iliac or common iliac arteries may also be accessed) |
| After gaining arterial access in the contralateral common femoral artery for the initial aortogram, what should be done next? | Place a vascular sheath and advance marker pigtail catheter to the proximal aortic arch. |

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| What injection rate and size marker pigtail catheter should be used for injection in the ascending aorta? | Injection rate of 15 cc/second for a total of 30 cc and 5- to 7-Fr pigtail catheter should be used. |
| The thoracic stent-graft delivery system should be advanced over what type of wire? | Super stiff 0.035″ guidewire |
| For the initial aortogram, how should the fluoroscope be positioned? | Left anterior oblique (LAO) to visualize the arch and accurately profile the great vessels |
| For the thoracic stent-graft deployment, how should the fluoroscope be positioned? | Perpendicular to the proximal landing zone |
| After advancing the endograft delivery system to the target site, how do you confirm positioning? | Locate the radiopaque markers and expose the first two springs. Ensure the proximal and distal springs are at adequate landing zones of at least 20 mm. |
| How should the thoracic stent-graft be deployed? | Under continuous fluoroscopic visualization to confirm positioning |
| What can be done to prevent migration of the thoracic stent-graft during deployment? | Maintain low mean arterial pressure (MAP) (60–70 mmHg) with the use of sodium nitroprusside. |

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| After deployment of the stent graft and careful withdrawal of the delivery catheter, what should be done next? | A completion angiogram to confirm stent-graft placement and absence of endoleak |
| What is the role of compliant balloon angioplasty? | It helps model the stent graft to the vessel wall to ensure wall apposition and seal |
| What if additional devices are needed for adequate coverage of the TAA? | Ensure an overlap of a minimum of 30 mm of the stent-graft material. In areas of angulation or curvature, an additional overlap of 50 mm is required with a minimum of 45 mm. |

## Complications

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| TAA can cause what types of complications? | Rupture, distal embolization, compression of adjacent structures (trachea, esophagus, pulmonary vein or artery, superior vena cava), stretching of the recurrent laryngeal nerve, fistula (trachea or bronchus, superior vena cava, esophagus), or infection |
| What are some early and late complications of the thoracic stent-graft placement? | Aortic perforation, endoleaks, stent fracture, and device malposition, migration, or collapse |

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| What is an endoleak? | An endoleak is the persistent perfusion of the aneurysm sac outside of the stent graft. Endoleak complications may occur up to 25% of the time. |
| What are the dreaded complications after treatment of a TAA? | Spinal cord ischemia (0.8–3%) resulting in paraparesis or paraplegia, anterior spinal syndrome, and cerebrovascular stroke (2.1–3.6%) |
| How can you prevent and reverse spinal cord ischemia? | Prophylactic CSF drainage should be considered in patients with prior history of abdominal aortic aneurysm repair, hypotension (mean arterial pressure < 70 mmHg), stent-graft coverage between T8 and L2, and treatment length >20 cm. If detected early, it may be reversed with prompt CSF drainage and maintaining a mean blood pressure between 80 and 90 mmHg. |
| What are the types of complications that can occur at the vascular access site? | Thrombosis, dissection, rupture, and avulsion |
| What is postimplantation syndrome? | It is a self-limited early complication of stent-graft placement, which usually resolves within a week. Patients may present with low-grade fever, elevated C-reactive protein, mild leukocytosis, and possible reactive pleural effusion. The symptoms usually resolve within 1 week and are managed with analgesics and anti-inflammatory agents. |

## Landmark Research

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| In the VALOR Trial, what was the bottom line of the 5-year follow-up with the Talent Thoracic Stent Graft? | TEVAR using the Talent Thoracic Stent Graft System demonstrated sustained protection from thoracic aortic aneurysm-related mortality, aneurysm rupture, conversion to surgery, and durable stent-graft performance. |
| What are the results of the VALOR Trial through the 5-year follow-up? | Kaplan-Meier estimates for freedom from all-cause mortality at 1 year and 5 years were 83.9% (standard error [SE] 2.6%) and 58.5% (SE 3.7%), respectively.<br>Estimated freedom from aneurysm-related mortality (ARM) at 1 year and 5 years was 96.9% (SE 1.3%) and 96.1% (SE 1.4%), respectively.<br>Freedom from secondary endovascular procedures was 81.5% (SE 3.3%).<br>5-year estimate of survival free from aneurysm rupture was 97.1% (SE 1.5%).<br>5-year estimate of conversion-free survival was 97.1% (SE 1.4%).<br>5-year estimate of freedom from stroke was 88.2% (SE 6.0%), and spinal cord ischemia (SCI) was 92.3% (SE 4.8%). |

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| What are the main lessons from the 5-year follow-up for treatment of thoracic aneurysms with TEVAR using the Gore TAG compared with open surgery? | At 5 years, no ruptures, one migration, no collapse, and 20 instances of fracture in 19 patients were noted in the TAG group with authors claiming occurred prior to the Gore TAG revision. Treatment of thoracic aneurysms is superior to surgical repair at 5 years:<br>Aneurysm-related mortality was lower for TAG 2.8% compared with open repair 11.7% ($P = 0.008$).<br>No differences in all-cause mortality between TAG 68% and 67% of open repair ($P = 0.43$).<br>Major adverse events were significantly reduced in the TAG group 57.9% vs open repair 78.7% ($P = 0.001$).<br>Endoleaks in the TAG group decreased from 8.1% at 1 month to 4.3% at 5 years. |

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| What are the 5-year results between open surgical repair and thoracic endovascular aortic repair with Zenith TX2 in the treatment of degenerative aneurysms and ulcers of the descending thoracic aorta? | Similar survival estimates from all-cause mortality for TEVAR were 62.9% and 62.8% for open repair and aneurysm-related mortality with TEVAR 94.1% compared with open repair 88.3%.<br>Kaplan-Meier estimates of freedom from severe morbid events (paraplegia, return to operating room for bleeding, and permanent dialysis) for TEVAR and open repair were 87.3% vs 64.3% at 1 year and 79.1% vs 61.2% at 5 years.<br>Kaplan-Meier estimates of freedom from secondary intervention were 91.5% for TEVAR and 88.4% for the open repair at 5 years.<br>TEVAR with the TX2 is a safe and effective alternative to open surgical repair for the treatment of anatomically suitable descending thoracic aortic aneurysms and ulcers. |

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| At the 2-year follow-up, what did the RELAY Endovascular Registry for Thoracic Disease II (RESTORE II) study demonstrate? | It showed the safety and effectiveness of RELAY and RELAY NBS stent grafts for elective endovascular thoracic aortic repair, as well as their lower rate of perioperative complication compared with the RELAY first-generation device.<br>Rate of all-cause 30-day mortality was 4.2% vs the RESTORE registry 7.2%.<br>Perioperative neurologic complications were lower in RESTORE II vs RESTORE study paraplegia/paraparesis (2.9% vs 2.0%) and stroke (0.6% vs 1.6%), respectively.<br>Device-associated complications were detected in 4.6% of the patients in RESTORE II vs 5.3% in RESTORE study.<br>Endoleak rate was 6.4% (type I 5.8% and type II 1.7%). |

## Common Questions

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| What are the types of endoleaks? | Type 1: Inadequate seal of proximal/distal attachment site<br>Type 2: Retrograde perfusion of the aneurysm via branch vessels<br>Type 3: Inadequate seal between endograft components<br>Type 4: Endograft porosity (rare)<br>Type 5: Endotension (aneurysm sac expansion without an identifiable endoleak on angiography or CTA) |

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| What is the most common type of endoleak? | Type 2 |
| Which type(s) of endoleak should be treated immediately? | Type 1 and type 3 because of the increased risk of aneurysm rupture secondary to the direct communication with high-pressure arterial blood. Type 1 endoleaks may be corrected by securing the attachment sites with balloon angioplasty to produce an adequate seal between the stent and vessel wall. If the vessel leak persists, then balloon-mounted bare metal stents or stent-graft extensions can be used to secure the attachment sites. Type 3 endoleaks may be corrected by covering the inadequate seal between endograft components with a stent-graft extension. If type 1 and type 3 endoleaks continue following an endovascular approach, then conversion to open repair should be considered. |
| What is the type of imaging surveillance recommended for clinical follow-up? | CTA may be performed at 1–3, 6, and 12 months. The CTA should include an unenhanced, enhanced arterial phase, and a delayed series to evaluate for endoleak, graft migration, or aneurysm sac enlargement. MRA can be used as an alternative to CTA in patients with renal disease (compatibility of stent graft must be verified prior to imaging the patient). Unenhanced images help visualize calcifications, which may be confused for an active arterial bleed or intramural hematomas, which are hyperdense on non-contrast studies and may be less obvious after contrast administration. |

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| What is the technical success rate for thoracic stent-graft placement? | 98–99.5% |
| At 1 year, what is the percentage of descending TAAs that remain stable or decrease (>5 mm) in size? | 91–92.9% |
| At 5 years, what is the aneurysm-related mortality of TAAs with TEVAR versus open surgery? | 2.8–5.9% with TEVAR compared with 11.7–12% for open surgery |

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# Chapter 19
# Angiography

**Mertalaine Mulatre**

## Evaluating Patient

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| What must the IR physician review prior to embarking on an invasive procedure? | If available, the evaluation of prior imaging and reports (noninvasive vascular studies, prior angiograms, and correlative imaging) is essential prior to the commencement of a procedure. Evaluation of the imaging helps the interventionalist identify the pathology to treat, determine a path for treatment when necessary, evaluate patency of vessels, and identify any anatomic variants. |
| After assessing the puncture site, what else must be evaluated? | When accessing the puncture site, documentation of any fresh surgical incision, the presence of an abdominal pannus, or cellulitis should be included. The strength of the pulses should then be recorded using a consistent system. If distal pulses are not palpable, Doppler may be utilized to assess pulses. |

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| What labs can be considered to obtain prior to a procedure? | Lab tests such as international normalized ratio [INR], prothrombin time (PT), activated partial thromboplastin time (aPTT), platelet count, and serum creatinine (Cr) may be considered to help identify patients at increased risk of bleeding or with underlying renal dysfunction. |
| What are the general guidelines for bedrest after a procedure? | Typically, approximately 6 hours after an arterial puncture and 4 hours after a venous puncture. |
| When discharging a patient, what must be considered and evaluated? | Although criteria for discharge can vary based on the procedure performed, in general prior to discharge, the patient should be able to tolerate a diet, have pain controlled with oral medications, have puncture site without complications, and have a family member or responsible adult available for transport to the patient's home. |
| What are the initial steps for evaluating a patient for peripheral arterial disease (PAD)? | Duplex sonography, ankle-brachial index (ABI), and pulse volume recordings are often used in conjunction to help ascertain the segment of arterial disease and its physiologic complications. The ABI is performed by using a blood pressure cuff or ultrasound to evaluate the pressure in the brachial artery in both arms and the anterior and posterior tibial arteries in both legs. The higher of the two brachial artery pressures and the higher of the anterior or posterior tibial artery pressures are used for the index. An ABI of 1.0–1.3 is normal, 0.4–0.9 indicates mild to moderate PAD, and 0.4 or lower indicates severe PAD. |

## High Yield History

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| What are the essential elements of a pre-procedure note? | The essential elements of a pre-procedure note include:<br>Current history and physical<br>Assessment of prior sedation and outcomes<br>Assessment of the airway, heart, and lungs<br>Procedural plan, including side or site of delineation of indicated<br>Plan for sedation, including drugs to be used<br>Level of sedation intended for the procedure |
| What are the Anesthesia Society of America (ASA) requirements for fasting prior to a procedure? | For moderate sedation and general anesthesia, the ASA requirements for fasting are 6 hours for solids and 2 hours for clear liquids in adults. Clear liquid examples include water, fruit juices without pulp, carbonated beverages, clear tea, and black coffee. |
| What is the ASA physical status classification system? | |

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| ASA I | A normal healthy patient |
| ASA II | A patient with mild systemic disease |
| ASA III | A patient with severe systemic disease |
| ASA IV | A patient with severe systemic disease that is a constant threat to life |
| ASA V | A moribund patient who is not expected to survive without the operation |
| ASA VI | A declared brain-dead patient whose organs are being removed for donor purposes |

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| What are the considerations for obtaining consent? | When obtaining consent, the interventionalist must describe the procedure in plain English to the patient. If the patient does not speak English, a medical translation service must be used. Whether speaking in English or using a translator, appropriate descriptions and associations should be made within the patient's field of understanding. The IR doctor must know and describe the risks, benefits, and alternatives of the procedure. They must also allow time for the patient to ask questions. Lastly, the patient should be able to describe the procedure in their own words. |
| What is the minimum information that must be in an immediate postprocedure note? | The minimum required elements to include in a procedure note include:<br>Postoperative diagnosis<br>Procedure(s) performed with brief description of each procedure<br>Findings<br>Primary surgeon and assistants<br>Estimated blood loss<br>Specimens removed |

## Relevant Anatomy

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| Where does the common femoral artery begin? What is the ideal position to access the femoral artery? | The common femoral artery (CFA) begins inferior to the inguinal ligament. It is important to avoid accessing the CFA above and below the inguinal ligament to decrease the risk of retroperitoneal hemorrhage and thigh hematoma, respectively. The ideal location to access the femoral artery is the inferomedial margin of the femoral head. This allows for utilization of the femoral head to aid with manual compression of the vessel above the arteriotomy site to achieve arterial hemostasis following sheath removal. |
| When does the superficial femoral artery become the popliteal artery? What are the branches of the popliteal artery? | As the superficial femoral artery (SFA) courses through the adductor hiatus, it becomes the popliteal artery. The branches of the popliteal artery are the geniculate and sural arteries, which supplies some of the structures in the knee and calf. The popliteal artery also gives rise to the anterior tibial artery and the tibioperoneal trunk. |
| When accessing the upper extremity for an abdominal aorta or lower extremity procedure, which arm should be used? Why? | The left upper extremity should be used because this allows the catheter to only cross one cerebral artery, the left vertebral artery. |
| Where does the brachial artery divide? What arteries does it divide into? | The brachial artery divides near the antecubital fossa. It divides into the radial and ulnar arteries, which course distally to form the deep and superficial palmar arches. |

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| What tests are used to ensure adequate perfusion to the hand before radial or brachial access? | The modified Allen test and Barbeau test are used to ensure preservation of flow to the hand. |
| What are common variations of the hepatic arterial supply? | Commonly encountered variants are replaced or accessory left hepatic artery originating from the SMA, replaced or accessory left hepatic artery originating from the left gastric artery, and replaced common hepatic artery originating from the SMA. |
| What upper extremity veins are considered a part of the superficial venous system? | The basilic and cephalic veins are a part of the superficial venous system. The veins connect in the antecubital fossa via the median cubital vein. |
| What lower extremity veins are considered a part of the deep venous system? | Anterior tibial, posterior tibial, peroneal, popliteal, and deep femoral and common femoral veins are considered a part of the deep venous system of the lower extremity. |

## Relevant Materials

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| What types of needles are used for vascular access? | Needles provide a central channel for introduction of a guidewire. Double wall needles consist of a metal cannula, stylet, and hub. The double wall needles are typically 18G or 19G. Single wall needles consist of beveled cannula and hub. They are typically 18G or 21G. |

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| What are the inner workings of a guidewire? | A guidewire consists of three parts: coil spring, mandrel, and wire guide. The outer portion of the guidewire is the coil spring. It is tightly coiled wire made of stainless steel. The mandrel, core of the guidewire, gives the guidewire its characteristics. The wire guide runs the length of the coil spring and prevents it from unraveling. Stainless steel wires are more prone to kinking, and nitinol wires are more flexible with less support, though wires can be made with combined materials. Larger core wires provide more support and torque, and can also aid in straightening of your equipment and the vessel. Smaller core diameter wires provide more flexibility and trackability, though are better suited for more tortuous vessels. |
| What is the difference between the core and the taper? | The "grind" is the constant diameter of the wire. Wires taper a certain distance from the constant diameter, which can either be broad (improved wire tracking) or short (greater tendency to prolapse, less atraumatic). From taper to grind (core-to-tip), there is a change in stiffness, which contributes to differences in steerability and tactile feedback. |
| What is the penetration power of a wire? | Penetration power is the tip stiffness divided over the area of the wire tip. Core-to-tip design incorporating high tip load with a reduced tip diameter generates higher tip pressure for any tip stiffness. Steerability refers to stiffness in the rotational axis and competes with softness (flexibility in bending/low tip loading). Corrugated core-to-tip designs contribute to rotational axis rigidity, which translates tactile feedback to the operator. |
| Guidewires are accepted through what needle gauge sizes? | The commonly used wire sizes are 0.038, 0.035, 0.018, and 0.014 cm. A 21-G needle accepts 0.018–0.021-cm wires. An 18G needle accepts 0.035–0.038-cm wires. |

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| What are catheters sized as? | A catheter's outer diameter is measured in French (Fr). One Fr equals 0.33 mm or 3 Fr equals 1 mm. |
| What are flush catheters and what are their uses? | They are nonselective catheters used to deliver large boluses of contrast to the large vessels of the body. They can have different tip configurations (pigtail, omni, and straight) to allow the interventionalist more control and options in directing flow of the contrast. |
| What is the size of microcatheters and what are their purposes? | Microcatheters are 1.5–3-Fr catheters. They are used in super selective interventions. |
| What are the characteristics of contrast agents? | Acceptable contrast agents should be relatively inert and soluble in blood and provide adequate opacification.<br>Iodinated agents may be ionic or nonionic:<br>Ionic agents are high-osmolar and less viscous/more reactive.<br>Nonionic agents are more inert and more viscous/less reactive:<br>Visipaque is based on the nonionic dimer, iodixanol, and is isoosmotic to blood plasma.<br>Omnipaque is based on the nonionic monomer, iohexol, and has an osmolality about twice that of plasma. |

## General Step by Step

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| What are some general guidelines for selecting an arterial access? | In selecting an arterial access, one should ensure a patent artery, a superficial location over the bone, healthy overlying skin, and communication with the artery of interest. |

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| What is the short-axis view (longitudinal approach) and the long-axis view (transverse approach) during an ultrasound-guided vascular access? | In a short-axis view, the image plane is perpendicular to the course of the vessel and to the needle (needle is "out of plane"). The vessel should appear as an anechoic circle on the screen with the needle visualized as a hyperechoic point in cross section. In a long-axis view, the image plane is parallel to the course of the vessel (needle is "in plane"). The image should show the course of the vessel across the screen and the shaft and point of the needle as it is advanced. |
| Describe the Seldinger technique. | The Seldinger technique consists of percutaneous puncture of a blood vessel with a hollow needle at a 45° angle. Once blood return is visualized, an atraumatic guidewire is introduced through the needle. The needle is then removed while the guidewire remains in place. An angiographic catheter is advanced into the vessel over the guidewire. Once the catheter is in the vessel, the guidewire is gently pulled out. |
| What is the terminology for injection rates? What are the typical injection rates? | "a for b" where "a" is rate of injection in mL/s and "b" is volume of injection |

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| Thoracic aorta | 20 mL/s |
| Abdominal aorta | 15 mL/s |
| Abdominal aortic bifurcation/iliac arteries | 5–10 mL/s |
| Femoropopliteal arteries | 4–6 mL/s |
| Celiac/SMA | 4–6 mL/s |
| Main pulmonary artery | 20 mL/s |

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| Selective right or left pulmonary artery | 10 mL/s |
| IVC | 10–20 mL/s |

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| When would a longer injection time be ideal? | Longer injections are ideal when studying a larger vascular bed, detecting a small or peripheral bleed, and studying the venous outflow of an organ. |
| What are the key steps for pulmonary artery angiography? | Before embarking on a pulmonary artery angiogram, a baseline EKG should be performed to assess for heart block. Insertion of a catheter or sheath can introduce a right bundle branch block. Patients with a left bundle branch block should have immediate access to pacing. Imaging during the angiography should be performed on full inspiration. An angled pigtail catheter or flow-directed balloon catheter should be used to quickly negotiate the right ventricle outflow tract and minimize contact and irritation with the right atrium and ventricle. Once in the main pulmonary artery, the intravascular pressure is measured. Normal pressure is roughly 25/10. |
| What is DSA? | Digital subtraction angiography refers to a process in which the radiologist attempts to acquire maximal diagnostic opacification of vessels, using the least amount of injected contrast material as possible. DSA removes, from the projection, non-opacified structures that are present on the pre- and post-contrast images (stationary anatomy). Body and organ movement results in misregistration artifact and incomplete subtraction of tissues. |

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| Why do individuals leave the angiosuite during a "run?" | Air kerma used in digital subtraction angiography is higher than air kerma used in conventional digital fluoroscopy to reduce quantum mottle. This is because images to be subtracted must be imaged (in order to identify stationary anatomy), as well as the structures opacified by the contrast. The subtracted image has approximate 40% more noise than the non-subtracted image and therefore requires a considerable increase in dose. |
| What is a roadmap? | A roadmap utilizes a single DSA reference image as a fluoroscopic "mask," which the fluoroscopy unit stores digitally. Live fluoroscopy images are then subtracted from projected mask, which allows the radiologist to detect the location of live catheters and wires with respect to the previously visualized opacified vessels (seen in the mask). |
| What is a fluoroscopic fade? | A roadmap utilizes a single DSA reference image from a prior angiographic "run" to serve as a mask for live fluoroscopy images. Therefore, it avoids repeat double exposure required for repeat DSA, as well as the need to administer additional contrast material. |
| What is the best DSA projection for imaging certain vessels? | The abdominal aorta is best seen via an AP projection. The internal iliac artery division is best seen via contralateral oblique projection. The internal iliac artery anterior division is best seen via the ipsilateral oblique projection. The femoral and popliteal/tibioperoneal bifurcations are best viewed via the ipsilateral oblique projection. The pedal vessels are best viewed in the lateral or contralateral oblique projection. |

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| What are some ways dose can be reduced during angiography? | Limiting use of magnification and DSA<br>Increasing the source-to-image distance<br>Utilizing pulsed fluoroscopy or decreased frame rates<br>Decreasing FOV and use of collimation and filters |

## Complications

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| What are the complications of vascular access? | Hematoma, pseudoaneurysm, thrombosis, arterial dissection, retroperitoneal hemorrhage, and arteriovenous fistula are complications of arterial vascular punctures. |
| What is the management for the above-stated complications? | If a hematoma develops, it is outlined with a marking pen and inspected at regular intervals to ensure no expansion. If the hematoma is massive and expanding, surgical evacuation may be required.<br>If an arterial dissection is not flow-limiting, it is managed with imaging surveillance. If it is flow-limiting, it is managed with balloon inflation across the dissection to reattach the dissected intima with the vessel media.<br>Nonocclusive thrombosis is managed with antiplatelet therapy. Occlusive thrombus is typically treated with surgical thrombectomy.<br>Retroperitoneal hemorrhage occurs when the CFA is accessed above the inguinal ligament or when primary hemostasis is not achieved with an appropriately placed puncture. Standard of therapy is surgical repair. If the patient is not a surgical candidate, a covered stent can be placed across the vascular injury. |

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| What is the management of a pseudoaneurysm? | The options for management of a pseudoaneurysm include observation, ultrasound-guided compression, ultrasound-guided thrombin injection, and surgery. Small pseudoaneurysms that are less than 2 cm can be observed with weekly duplex ultrasound until thrombosis occurs. They can also be managed with ultrasound-guided compression or ultrasound-guided thrombin injection. If a pseudoaneurysm is >2 cm, has a short (<4 mm) neck width, is enlarging, or is associated with significant pain, surgical repair may be necessary. |
| What are the complications of venous punctures? | Venous complications include perforation of vein, thrombosis of puncture site, hematoma, and inadvertent arterial injury. In the jugular and thoracic veins, complications include pneumothorax, hemothorax, and air embolism. |
| What is the management of central venous air embolism? | Control source, turn patient to left decubitus position, administer oxygen, and aspirate air from the heart with catheter. |
| How is wire- or catheter-induced vasospasm managed? | Nitroglycerin can be directly injected. It is typically provided as a bolus between 50 and 300 mcg and has a nearly immediate onset. Nitroglycerin must be used with caution in patients taking PDE5 inhibitors. Intra-arterial verapamil can also be used. It is typically given as a 2.5–5-mg bolus. Its onset of action is within a few minutes and lasts 20 minutes. |

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# Chapter 20
# Peripheral Arterial Disease

**Omowunmi Ajibola and Abeer Mousa**

## Evaluating Patient

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| What is the prevalence of peripheral artery disease (PAD)? | According to a 2010 estimate, there are about 200 million people worldwide living with PAD. In the United States, PAD affects about 8–12 million people, with many cases remaining undiagnosed. As of 2015 in the United States, an estimated 5,04,000 individuals (of a total estimated population of 295.5 million) were living with a major amputation due to PAD; this is a number that is projected to more than double by 2050. |

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| What exam techniques are used to evaluate patients for PAD? | Physical exam consists of evaluating the limb at risk for skin color changes, swelling and erythema, ulcers, wounds, and so on. It also consists of a head-to-toe evaluation of the patient looking for carotid bruit, irregular heartbeat or heart rhythm, and abdominal bruit. An ankle-brachial index (ABI) is usually the first noninvasive test used to assess PAD. It is 95% sensitive and 100% specific. It is important to remember that heavily calcified arteries have diminished compressibility, often seen in diabetics and those with end-stage renal disease, which can falsely elevate the results of the test. |
| How is an ABI performed and what is the interpretation of the values? | The ABI test is a noninvasive exam which is used to evaluate for PAD. A cuff is placed around the limb – usually the upper arm and ankle – and is inflated to a pressure just above the systolic blood pressure. Then, an ultrasound Doppler probe is used to locate the brachial artery in the arm and dorsalis pedis or posterior tibial artery at the level of the ankle. The cuff is then slowly deflated and the pressure when return of signals is audible is recorded. This is done on each side. The higher of the posterior tibial artery or dorsalis pedis pressures is divided by the highest brachial artery pressure to calculate the ABI. The values are as follows:<br>0.9 – < 1.3: Normal<br>< 0.9 – .7: Mild PAD<br>< 0.7 – .4: Moderate PAD<br>< 0.4: Severe PAD |
| What is the Rutherford classification for chronic limb ischemia? | This is a way of classifying the symptoms of chronic limb ischemia to help determine the course of action in regard to interventions and treatment. |

| Category | Clinical description | Objective criteria |
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| 0 | Asymptomatic – No hemodynamically significant occlusive disease | Normal treadmill or reactive hyperemia test |
| 1 | Mild claudication | Completes treadmill exercise; AP after exercise > 50 mmHg but at least 20 mmHg lower than resting value |
| 2 | Moderate claudication | Between 1 and 3 |
| 3 | Severe claudication | Cannot complete standard treadmill exercise, and AP after exercise < 50 mmHg |
| 4 | Ischemic rest pain | Resting AP < 40 mmHg; flat or barely pulsatile ankle or metatarsal PVR; TP < 30 mmHg |
| 5 | Minor tissue loss nonhealing ulcer, focal gangrene with diffuse pedal ischemia | Resting AP < 60 mmHg, ankle or metatarsal PVR flat or barely pulsatile; TP < 40 mmHg |
| 6 | Major tissue loss extending above the tarsometatarsal level, functional foot no longer salvageable | Same as 5 |

*AP* ankle pressure, *PVR* pulse volume recording, *TM* tarsometatarsal, *TP* toe pressure

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| What is "chronic limb-threatening ischemia" (CLTI versus "critical limb ischemia" (CLI)? | According to the 2019 Global Vascular Guidelines, CLTI is a clinical syndrome defined as PAD in combination with rest pain, gangrene, or a lower limb ulceration greater than 2 weeks of duration. As opposed to CLI, which relies on a threshold ABI value for diagnosis, CLTI represents more of a continuum of disease. |

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| Which PAD patients are at greatest risk for development of CLTI? | In patients with known PAD, the risk for development of CLTI appears to be greater in men, in patients who have had a stroke or are in heart failure, and in patients with DM (strongest association). Patients who present de novo with CLTI (no prior diagnosis of PAD) seem more likely to be older and male and to have pre-existing cardiovascular disease (including hypertension, myocardial infarction, heart failure, or stroke), as well as renal failure. |
| Typically, at what ABI value in chronic limb ischemia are findings of CLTI (tissue compromise and pain at rest) present? | Below an ABI of 0.3 – 0.4. Below this level is associated with high amputation rate (30%) and mortality (25%). |
| When are toe pressures or toe-brachial index (TBI) utilized? | TBIs are used when tibial vessels are heavily calcified, thus providing inadequate compressibility to be analyzed by the ABI. A normal TBI is > 0.75. When suspecting CLTI, toe pressures and TBI are the preferred measures. |
| In addition to ankle and toe pressures, indices, and waveforms, what else should be assessed? | Additional noninvasive measurements, such as pulse volume recording (PVR), transcutaneous oximetry, or skin perfusion pressure, are used. PVR detects changes in volume of blood flow. This is measured at multiple levels along the extremity, and the magnitude and contour of PVR readings between segments is compared. |

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| What labs should be ordered during patient evaluation? | There are many risk factors for vascular disease that can be evaluated with lab tests, including a lipid panel and fasting blood glucose. Routine blood tests such CBC, BMP/CMP, aPTT, and PT/INR may be obtained prior to angiography. Evaluating for hereditary and acquired risk factors for hypercoagulable disease can be important in certain patients to identify whether there are other reasons for vascular insufficiency. |
| What medical conditions may mimic arterial claudication and what must be excluded before diagnosing PAD? | Venous claudication related to DVT and venous insufficiency, neurogenic claudication, musculoskeletal pain, vascular malformations, pelvic congestion, and tumors or masses all may mimic arterial claudication. Specific inquiries about the pain should explore duration, location, progression, reproducibility with exercise, and amount of rest time necessary for symptoms to resolve. Venous, traumatic, embolic, and nonatherosclerotic etiologies should be excluded before making a diagnosis of CLTI. |

## High Yield History

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| What is angioplasty and what are the common conditions treated by angioplasty/stenting? | Angioplasty is a minimally invasive procedure where a pressure-inflated balloon is used to open a narrowed or occluded blood vessel by breaking apart any plaque in the vessel wall and stretching the vessel wall. There are many indications for stenting, and the exact reasons why the stent was placed (including progression or improvement in disease), the type of stent, location, and evident complications or in-stent stenosis as well as all interval studies and total indwell time should be documented. Stents can be uncovered, covered, self-expanding, or balloon-expandable. The type of stent placed depends on underlying anatomy and the specific indication. |
| What are the risk factors associated with PAD? | The most common risk factor is atherosclerosis. Other risk factors are chronic kidney disease or CKD, diabetes mellitus, tobacco use, diet, obesity, high blood pressure, and high cholesterol. |
| What are the characteristic clinical symptoms in patients with PAD? | Patients usually present with pain in the affected limb with exercise or walking and relief of symptoms at rest. Other characteristic symptoms include numbness and/or paresthesia, cramping, skin ulcers or gangrene, hair loss in the affected area, and weakness of the affected limb. In patients with severe disease, there is no symptom relief at rest, also known as *rest pain*. Rest pain is typically located in the mid or forefoot and can be present at all times throughout the day, and even awaken the patient from sleep. |

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| What is the characteristic description of ischemic rest pain? | This is pain of the affected limb at rest and it represents progression of ischemia. It is made worse with elevation and is better with the limb in a dependent position. The pain is usually worse with cold exposure and better with heat exposure. It is associated with one or more of the following abnormal hemodynamic parameters:<br>ABI < 0.4Ankle pressure < 50 mmHg<br>Toe pressure < 30 mmHg<br>Transcutaneous partial pressure of oxygen ($TcPO_2$) < 30 mmHg<br>Flat or minimally pulsatile pulse volume recording waveforms |
| What is Leriche's syndrome? | This is the triad of buttock and thigh claudication, diminished femoral pulses, and impotence, which indicates aortoiliac occlusive disease. |
| Based on the described location of claudication by the patient, how may the physician localize the likely level of disease? | If confined to the calf, it is likely the superficial femoral or popliteal artery disease, though more proximal disease cannot be excluded.<br>If it involves the thigh and calf, it is likely due to common femoral or external iliac artery disease. |
| What should you suspect in a young patient with PAD and no other risk factors? | Hyperhomocysteinemia. Homocysteine levels are higher in several case-control PAD cohort studies, although the benefits of folate supplementation appear to be negligible. The disease is characterized by toxicity to endothelial cells and the reduced ability to generate and release nitric oxide, arterial wall inflammation, and smooth muscle cell proliferation, as well as increased levels of plasminogen activator inhibitor. |

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| What is the difference between acute and chronic limb ischemia? | Acute limb ischemia is a new and sudden onset of limb pain with changes in neurological function of the said limb, in a patient who was previously not symptomatic. Acute limb ischemic changes may be superimposed on a patient with underlying chronic limb ischemia, as well. |
| What characteristics of the occlusion are important for understanding the outcomes of angioplasty? | The percentage of arterial stenosis and the length of the occlusion. |
| Describe patency of stents. | Primary patency: Time from original intervention to a second intervention, such as angioplasty, atherectomy, or thrombolysis, in which patency is restored. In other words, it is how long patency is maintained without any repeat intervention.<br>Primary-assisted patency: Primary patency time period plus time gained from a second intervention that was required to maintain patency. This defines the durability of an intervention that failed (but not to the level of thrombosis) and required a second intervention to maintain patency.<br>Secondary patency: Time from initial intervention to a second intervention, such as catheter-directed thrombolysis or thrombectomy, which is required to treat specifically thrombosis or occlusion. Secondary patency refers to the durability of the second intervention in this respect. |
| What is critical stenosis? | Critical stenosis refers to critical narrowing of a vessel which results in significant reduction in maximum blood flow to a distal area. This is the area that is usually targeted during the process of angioplasty and stenting. |

## Indications/Contraindications

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| In the field of interventional radiology, what is the most common indication for angioplasty and stenting? | Peripheral artery disease (PAD). Other indications include renal artery stenosis, central venous occlusion, and stenoses of dialysis AV fistulas or grafts. |
| What are the indications for intervention in patients with PAD? | Patients with critical limb ischemia or those who have moderate or severe claudication and do not respond to maximal medical therapy |
| Lesions with what characteristics are better treated percutaneously? | Short segment stenosis or occlusions<br>Concentric, noncalcified stenosis<br>Distal runoff to vessels downstream |
| What are some contraindications to angioplasty and stenting? | There are no absolute contraindications for angioplasty and stenting. A relative contraindication includes patients with chronic kidney disease. |
| What are the TASC guidelines? | The TASC II or TransAtlantic Inter-Society Consensus for the Management of Peripheral Arterial Disease are guidelines made to provide recommendations in the evaluation, diagnosis, and treatment of patients with PAD. The most utilized parts of these guidelines are the anatomical classification of the pattern of disease and guidance of revascularization strategy (open vs. endovascular) based on anatomical location and complexity of disease. The revised TASC II guidelines resulted in reclassification of more complex anatomies into less severe categories and therefore amenable to endovascular management. The classifications of lesions are as below. |

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| TASC A | Endovascular method with excellent results and should be the treatment of choice |
| TASC B | Endovascular method with good results and should be the preferred treatment unless an open revascularization is required for another associated lesion in the same anatomic area |
| TASC C | Open revascularization produces superior results compared to endovascular means, and endovascular treatment should be reserved for patients at high risk for open repair |
| TASC D | Endovascular methods do not yield good enough results to justify as the primary treatment. Open repair is preferred |

What is the TASC II classification of aortoiliac disease?

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| TASC A | Uni-/bilateral common iliac artery stenosis<br>Uni-/bilateral < 3 cm external iliac artery stenosis |
| TASC B | < 3 cm stenosis of infrarenal aorta<br>Unilateral common iliac artery occlusion<br>Unilateral stenosis > 3 cm or occlusion of the external iliac artery not involving internal iliac or common femoral arteries |
| TASC C | Bilateral common iliac artery occlusion<br>Heavily calcified external iliac artery occlusion<br>Bilateral external iliac artery stenosis or unilateral external iliac artery occlusion extending into the common femoral or internal iliac arteries |
| TASC D | Infrarenal aortic occlusion<br>Unilateral common and external iliac artery occlusion<br>Bilateral external iliac artery occlusion<br>Iliac stenosis in patients needing open AAA repair<br>Diffuse aortoiliac artery occlusive disease |

Trials evaluating surgical vs. endovascular treatment of lesions, especially of TASC C and D lesions, are difficult to perform and are uncommon. Current data shows that endovascular procedures are associated with lower complication rates, shorter length of stay, and lower hospital costs than surgical management. Recent meta-analyses have demonstrated good primary and secondary patency rates of TASC C-D lesions treated endovascularly.

What is the TASC II classification of femoral-popliteal disease?

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| TASC A | Single stenosis < 5 cm |
| TASC B | Multiple < 5 cm stenosis/occlusion<br>Single < 15 cm stenosis/occlusion not involving the infrageniculate popliteal artery<br>Heavily calcified < 5 cm occlusion<br>Single popliteal stenosis |
| TASC C | Multiple stenosis/occlusion > 15 cm<br>Recurrent stenosis/occlusion after two endovascular interventions |
| TASC D | Chronic total occlusion of common femoral or superficial femoral artery > 20 cm involving the popliteal artery<br>Chronic total occlusion of popliteal artery and proximal trifurcation |

As with aortoiliac disease, enrollment in trials comparing surgical to endovascular management of femoropopliteal disease is difficult. Comparing the results of these treatments is also difficult as patients referred to endovascular therapy often have intermittent claudication, whereas those referred to surgery often have CLTI, which is associated with increased periprocedural morbidity and mortality.

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| Why has endovascular therapy become the primary strategy for the treatment of symptomatic PAD? | Due to many factors such as improvement in vascular testing and imaging, improvement of the technology used in endovascular treatment, and decreased length of time in the hospital and with recovery |

## Relevant Anatomy

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| What are the different levels of disease in PAD? | Aortoiliac (buttock and thigh claudication), femoropopliteal (calf claudication), and infrapopliteal (plantar claudication). Below-knee arteries typically become increasingly involved as the overall severity of disease worsens. |
| What layers of the arterial wall are affected by angioplasty? | There arterial wall is made of three parts. From outside in they are the adventitia, the media, and the intima. Angioplasty is considered controlled vessel wall injury. The intraluminal plaque can compress and fracture, the intima can separate, and the media can stretch. Over time, this leads to a reparative response by the vessel termed "neointimal hyperplasia," a major contributor to in-stent restenosis. |

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| What are the major collateral pathways for lower extremity blood supply in aortoiliac occlusive disease? | They are as follows:<br>Pathway of Winslow: Subclavian artery → internal thoracic artery → superior epigastric artery → inferior epigastric artery → external iliac artery.<br>SMA → IMA → superior rectal artery → middle and inferior rectal arteries → internal iliac artery → external iliac artery.<br>Lumbar, intercostal, subcostal arteries → deep circumflex iliac artery → external iliac.<br>Lumbar, intercostal, subcostal arteries → iliolumbar and lateral sacral arteries → internal iliac → external iliac artery.<br>Uncommon pathway can develop between the gonadal artery and the inferior epigastric artery with flow back into the common femoral artery and subsequently down the leg. |
| Which outflow artery is most commonly associated with intermittent claudication? | Superficial femoral artery |
| Which artery tends to be most diseased in patients with CLTI and infrapopliteal disease? | Popliteal and tibial arteries are more commonly associated with CLTI due to the lack of collateral vascular pathways by these lesions. Posterior tibial artery is most often diseased with relative sparing of the peroneal artery. In patients with DM, there may also be sparing of the DP artery. |

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| What is a persistent sciatic artery? | During normal embryological development, the axial artery regresses to the inferior gluteal artery, and the superficial femoral artery becomes the dominant artery to the leg. In 0.5% of individuals, this regression does not occur, and the axial limb artery persists as a continuation of the internal iliac artery along the posterior buttocks through the greater sciatic foramen below the piriformis muscle, into the thigh alongside the sciatic nerve eventually anastomosing with the popliteal artery. Posterior positioning makes the artery susceptible to repetitive injury and aneurysm formation, and patients may present with a painful posterior mass or distal extremity ischemia from thromboembolic disease. |
| What is a dominant peroneal artery? | Also known as peroneal magnus, this is when the peroneal artery is the sole main artery that continues below the knee, branching at the ankle to supply the dorsalis pedis and posterior tibial arteries. There are different forms of this anatomy with variable hypoplasia or aplasia of the anterior and posterior tibial arteries. |

## Relevant Materials

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| What is the difference between compliant and noncompliant balloons? | According to the law of Laplace, tension (hoop stress) within a balloon is equivalent to the pressure × diameter. Compliant balloons may dilate in certain areas beyond their stated diameter and can be used to mold a stent graft, for example, in the aorta. Noncompliant balloons will not dilate beyond their stated diameter, even at pressures much higher than nominal. |

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| What is the difference between nominal and burst pressure? | Nominal pressure is the insufflation pressure required for the balloon to reach its stated diameter. Burst pressure is the pressure at which 99.9% of balloons will not rupture with 95% confidence. |
| What is the difference between "over-the-wire" and monorail balloon delivery systems? | In an over-the-wire system, the guidewire enters the balloon catheter and remains in the catheter along the entire length of the balloon, exiting at the distal catheter opening. This system has good pushability, though is prone to loss of wire positioning during balloon removal. In the monorail system, the guidewire enters the balloon catheter but exits the catheter through a side port of the balloon catheter. This system is less pushable, though allows for more rapid wire exchange. |
| What two types of stent configurations are available? | Balloon-expandable and self-expandable stents. Either stent can have open (flexible) or closed (less flexible, less risk of plaque protrusion) cell design, and either stent can be covered or uncovered. |
| Where are they commonly used? | Balloon-expandable stents are stiff with high radial strength to avoid vessel recoil, which make for good use in a vessel with a calcified ostial lesion. These stents are sized 1:1 to the vessel and need a balloon to be properly deployed. Self-expandable stents have high elasticity and shape memory with low radial force, meaning they are more flexible and are usually placed in tortuous vessels or those which may experience movement such as the iliac and femoral arteries. Self-expandable stents should be slightly oversized by approximately 10–15%. Balloon-expandable stents are not suited for anatomical areas of flexion as this can lead to permanent crushing of the stent. |

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| What is a drug-eluting stent? | Drug-eluting stents may contain polymer (Eluvia; Boston Scientific) or polymer-free (Zilver PTX; Cook Medical) coating containing a chemotherapy drug, paclitaxel, which is an antimitotic agent. The rationale for drug coating is to help prevent the process of neointimal hyperplasia and in-stent restenosis and improve patency of stents. It is important to remember that neointimal hyperplasia is reparative response of the artery to angioplasty, and while it contributes to in-stent restenosis, it is actually protective against platelet aggregation. Therefore, dual antiplatelet therapy following these procedures is very important. |

## General Step by Step

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| What is the preferred access site for PAD treatment? | The choice of access is variable and dependent on disease location and extent, coexisting iliac and femoral disease, and plaque morphology. Depending on the planned treatment, access can be unilateral or bilateral, ipsilateral or contralateral, or even be approached from the upper extremity (axillary, brachial, radial). Traditionally, retrograde femoral artery access is most common and is most safely performed under ultrasound and fluoroscopic guidance over the level of the femoral head. |

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| What is the next step after gaining arterial access and placing a sheath? | This is to connect the sheath to a continuous drip of heparinized saline and use a wire to gain access to the true lumen of the vessel across the lesion to be treated. Occlusions may require hydrophilic wires and angled braided catheters for directional change. Heparinized saline is given to prevent clot formation which can break up and flow downstream causing new, distal vessel occlusion. |
| What is vessel preparation? | Operators may choose to "prep" the vessel with atherectomy to decrease the amount of disease in the vessel prior to angioplasty and stent placement, which can help in enhancing the effects of angioplasty, reducing the chances for dissection, and improve luminal gain and drug delivery from stents. There are many atherectomy devices available, as well as protective devices for distal embolization, which can be used concurrently to trap any dislodged clots. |
| What if I can't cross an occlusion or my wire enters the subintimal space? | Sometimes, plaque morphology favors approach from the opposite direction, so retrograde access beyond the lesion may be considered. If planning stent placement, reentry devices are available to bypass the lesion in the extra-intimal space and then reenter the true lumen beyond the level of disease. |
| What do I do after I deploy a stent? | Balloon angioplasty can be performed after deploying self-expanding stents to promote good wall adherence. Postprocedural angiography should be performed at the level of the disease to ensure good inline flow, as well as in the distal extremity to document any improved flow or distal capillary blush. |

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| What is a closure device? | Manual pressure above the arteriotomy site can be utilized to achieve hemostasis, typically for 10–15 minutes or even longer in an anticoagulated patient. Closure devices are tools that can deposit thrombogenic material on top of the arteriotomy site or introduce a suture to close the arteriotomy, which helps in achieving hemostasis. These tools should be supplanted by manual pressure and close observation for possible incorrect deployment or device failure. |

## Complications

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| Aside from access complications, what complications can occur during an endovascular procedure? | Remember that angioplasty is controlled vessel injury and there is always a risk of vessel wall rupture and/or dissection, which may be visualized as a dissection plane or extraluminal contrast extravasation. Procedural pearls are to never lose wire access across a lesion and always have a balloon and covered stent available to tamponade bleeding. The most common complication is distal occlusion secondary to emboli from an atherosclerotic plaque. Other complications are distal occlusion secondary to emboli from an atherosclerotic plaque or new clot, which can form during the procedure if heparinized saline fails to run through the vascular sheath. |
| What are some more late-term complications? | Stent fracture, stent migration, and stent collapse. |
| How do you monitor for acute complications? | Evaluation of the puncture site, femoral, and distal pulses should be checked routinely during the immediate post-op period and daily until the patient is discharged from the hospital. |

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| What are the complications that can occur at the puncture site? | Dissection, thrombosis, pseudoaneurysm, and fistula. |

## Landmark Research

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| What was the goal of the PARC study? | The PARC study was designed to address the lack of standardized definitions in the field of lower extremity peripheral artery disease research. The Peripheral Academic Research Consortium (PARC), the US FDA, and the Japanese Pharmaceuticals and Medical Devices Agency joined forces to develop a set of definitions for clinical characterization and treatment options to be used by clinicians, researchers, and medical device developers. |
| What are some things that were defined by the PARC study? | The study helped define patient symptoms according to already existing classification systems – the Fontaine and Rutherford systems. Other definitions were established in the following categories:<br>Anatomy, including characteristics of lesions and vessels<br>Acute procedural outcomes<br>Clinical outcomes<br>Imaging and physiologic surrogate endpoints |
| Why were these definitions important? | They are important because it helps classify patients into groups that be easily followed in research when evaluating new therapies as well as continued improvement of existing treatment options. It allows for all parties involved in the diagnosis and treatment of PAD to have a common language, allowing research in this field to grow. |

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| What is the INPACT trial? | The IN.PACT SFA trial was a prospective multicenter randomized controlled trial that involved 331 patients to compare drug-coated balloon (DCB) angioplasty with traditional percutaneous transluminal angioplasty (PTA) in the treatment of superficial femoral artery (SFA) and proximal popliteal artery disease. There were many other clinical trials that addressed similar goals, including the LEVANT and the RAPID trials; however, the INPACT trial was the largest prospective, multicenter, randomized trial. |
| What are the results of the INPACT trial? | The IN.PACT SFA trial showed that DCB was superior to PTA in improvement of patient outcomes for peripheral arterial disease and that they had a favorable safety profile when treating femoropopliteal arterial disease. |
| How were the results demonstrated in functional outcomes? | Functional outcomes for both investigational and control groups were unchanged from baseline in terms of quality of life. Both groups also demonstrated improvement from baseline in terms of walking impairment in a period of 12 months; there was no statistical difference in both groups. |
| So then, how are DCBs more effective than PTAs? | Three- and five-year data shows patients that underwent DCB had better primary vessel patency and a marked reduction for revascularization and retreatment of the target lesion. This means that DCBs were able to keep areas of critical stenosis open longer and reduced the need for retreatment of the area down the road. Although functional outcomes were similar across both groups, DCB proved to be safer and with less complications. |

## Common Questions

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| What is the pre-procedure status for a patient? | Patients should not eat or drink anything at least 4–6 hours before their procedure. Patients who take medications should discuss with their doctor which medication can and cannot be taken the day of the procedure and, also importantly, when certain medications can be stopped and resumed after the procedure. |
| Why is patient follow-up important? | It is important to monitor results of the intervention performed and to prevent further disease progression. |
| Is there a standardized imaging technique or protocol when it comes to patient follow-up? | There has not been much vigorous research and trials in regard to the timeline for patient follow-up and what imaging study should be used to evaluate the patient. There is an agreement that the same imaging modality should be used when following patients to have stable comparisons. |
| What is the modality of choice for imaging follow-up? | The modality of choice for follow-up is ultrasound. There are many advantages to this modality such as being noninvasive, low cost, wide availability, and lack of radiation. The major disadvantages are its operator dependent and artifacts on imaging which can happen with calcifications and stents. |

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| What other modalities are used for follow-up? | Other imaging modalities include computer tomography angiography or CTA and magnetic resonance angiography or MRA. CTA is a noninvasive imaging modality that is widely available, is not significantly operator dependent, can be rapidly performed, and can accurately evaluate the complications of PAD intervention. Disadvantages of CTA are ionizing radiation and the risk of contrast-induced contrast injury. MRA is another noninvasive imaging modality that can be used to evaluate PAD interventions. Limitations include artifacts such as susceptibility and flow-related. |
| What are some important actions after a procedure is done? | Patients are usually advised and encouraged to stop smoking. Patients are also started on antiplatelet therapy; most patients are started on aspirin and Plavix. Patients are also encouraged to exercise and eat healthy food. These are just as important as the procedure in ensuring long-term success. |
| When should a person be seen for clinical follow-up? | Patients are usually seen in clinic for the first time 1 month after their intervention. Imaging should have been done before the visit. A good history and physical should be performed including examination of the affected extremity. |

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# Chapter 21
# Acute Venous Thromboembolic Disease

**Sabeeha Chowdhury and Peyton Cramer**

## Evaluating Patient

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| Acute venous thromboembolic (VTE) disease includes which two entities? | Deep vein thrombosis (DVT) and pulmonary embolism (PE) |
| What is a deep vein thrombosis (DVT)? | Deep vein thrombosis refers to the presence of thrombus, or blood clot, within veins of deep compartments of the body, most commonly within the lower extremities. Thrombi within superficial veins are not DVT but are a part of a separate more benign entity known as superficial thrombophlebitis. |

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| How does an acute DVT present? | Most will have symptoms at the site of thrombus such as swelling, warmth, pain, tenderness, or skin redness. |
| How are DVTs classified? | By the duration of symptoms:<br>Acute: 0–14 days<br>Subacute: 15–28 days<br>Chronic: Greater than 28 days |
| What is a pulmonary embolism (PE)? | A pulmonary embolism refers to the intravascular migration of a venous thrombus to a pulmonary artery through the process of clot fragmentation and embolization. |
| What is the difference between a low-risk, intermediate-risk, and high-risk PE? | A low-risk PE is defined by the absence of right heart strain (as indicated on imaging as a RV:LV < 0.9), a PESI score less than 1, or a patient lacking significant clinical symptoms. An intermediate-risk PE is defined by right heart dysfunction (RV:LV ≥ 0.9) or PESI score ≥ 1 in the setting of normal systemic blood pressure. Intermediate-risk PE is further divided into intermediate low risk and intermediate high risk based on the absence or presence, respectively, of elevated cardiac biomarkers. A high-risk PE indicates that there is severe right heart dysfunction resulting in sustained hypotension (systolic blood pressure < 90 mmHg for at least 15 minutes or requiring inotropic support). |

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| What is the Pulmonary Embolism Severity Index (PESI) and how is it used in PE management? | The PESI score is a risk stratification tool that can be used to determine risk of mortality and long-term morbidity in patients with newly diagnosed PE. This score takes into account 11 clinical criteria including age, gender, history of malignancy, history of heart failure, history of chronic lung disease, heart rate ≥ 110, systolic blood pressure < 90, respiratory rate ≥ 30, temperature < 36°C, altered mental status (AMS), and oxygen saturation (SpO2) < 90. Various points are given for each clinical feature (with the heaviest weight placed on AMS, history of malignancy, and hypotension) to place patients into risk categories. These categories are associated with the following 30-day mortality rates:<br>Very low risk: 0–1.6%<br>Low risk: 1.7–3.5%<br>Intermediate risk: 3.2–7.1%<br>High risk: 4.0–11.4%<br>Very high risk: 10.0–24.5%<br>This tool can also aid in distinguishing which patients can be treated as an outpatient and which require higher level of care. Very low- and low-risk patients are often considered for outpatient treatment of PE (anticoagulation and follow-up care in the PE/DVT clinic, with a primary care physician, and hematology); however, the decision ultimately takes into account the entire clinical scenario. |
| What is the utility of echocardiogram in evaluation of pulmonary embolism patients? | Echocardiogram provides very useful data in the evaluation of right heart strain and cardiac physiology, including potential identification of a PFO. |

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| What symptoms should raise the suspicion for a pulmonary embolism? | Rapid onset dyspnea, pleuritic chest pain, hypoxia, tachycardia, and an increased alveolar-arterial oxygen gradient without another obvious explanation |
| What is May-Thurner syndrome? | May-Thurner syndrome is an anatomic variant in which the left common iliac vein is compressed by the right common iliac artery against the lumbar spine. This compression may result in left lower extremity thrombus formation related to the altered flow mechanics in this disease state. |
| What is a paradoxical embolism? | A venous thromboembolism that traverses through an intracardiac or pulmonary (right-to-left) shunt and embolizes into the systemic circulation. Depending on the site of embolization, this can lead to stroke, myocardial infarction, gastrointestinal ischemia, renal infarction, or ischemic extremities. |
| What is post-thrombotic syndrome (PTS)? | PTS is a chronic condition related to venous outflow obstruction, inflammation and valve destruction, and negative remodeling of the veins. It is characterized by high venous pressures and can present clinically as varicose veins, venous stasis dermatitis, venous stasis ulcers, and venous claudication. Venous hypertension and inflammation can lead to increased vessel permeability and lymphedema. |

## High Yield History

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| What is Virchow's triad? | Three factors that predispose to thrombus formation: slow blood flow, hypercoagulability, and endothelial damage. |
| What are some genetic causes of hypercoagulable states? | Factor V Leiden (most common), antithrombin III deficiency, protein C deficiency, protein S deficiency, hyperhomocysteinemia, and prothrombin G20210A mutation |
| What are some acquired causes of hypercoagulable states? | Surgery, trauma, malignancy, immobilization, smoking, obesity, nephrotic syndrome, and oral contraception pills |
| What is a Wells score? | The Wells score is a noninvasive scoring system to determine the pretest probability of having an acute PE. A score of four or less makes a PE "unlikely," whereas a score of greater than four points makes a PE "likely." |
| What factors are incorporated into the Wells score? | Clinical signs and symptoms of DVT, heart rate >100 bpm, previous immobilization or surgery, previous PE or DVT, hemoptysis, or recent malignancy |
| What is the best test for a patient with low probability of having VTE? | D-dimer is often used because of its high sensitivity. A negative test can rule out acute thrombus; however, a positive test is inconclusive because it is nonspecific. |
| What is the best test for a patient with a high probability of having a DVT? | Ultrasound with Doppler. The four signs seen on ultrasound include non-compressibility of the vein, intraluminal echogenicity, loss of flow, and loss of augmentation response. The most specific sign is non-compressibility of the vein. |

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| What are the important electrocardiographic considerations for pulmonary embolism? | Sinus tachycardia is the most common finding. The S1Q3TE pattern is the "classic" finding; however, it is rarely present. Another important finding to be aware of is left bundle branch block (LBBB), in which there is widening of the QRS interval and patients are susceptible to complete heart block during pulmonary angiogram or intervention (risk of RBBB and therefore complete heart block). These patients should be checked for a permanent pacemaker, should have minimal manipulation of the RV septum during intervention, and should be considered for backup temporary pacing or electrophysiology consultation. |
| What findings on plain film suggest a pulmonary embolism? | Wedge-shaped peripheral airspace disease (Hampton hump), focal oligemia (Westermark sign), prominent central pulmonary artery (knuckle sign), or prominent right main pulmonary artery (Fleischner sign) |
| What is the best test for a patient at high risk for PE? | Computed tomography pulmonary angiography (CT-PA) because the fast data acquisition, thin slices, and rapid bolus of IV contrast injection produce maximal opacification of the pulmonary arteries with little or no motion artifact. CT-PA has a sensitivity in excess of 90% for identifying partial or complete filling defects within the pulmonary arteries. |

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| What is the significance of the RV to LV ratio? | An increased RV to LV ratio is one of the criteria used to risk stratify patients between low and intermediate risks. An important concept to understand here is RV/LV interdependence. As the RV pressure increases from pulmonary hypertension, the interventricular septum is pushed into the LV cavity, which impairs diastolic filling and reduces cardiac output and blood pressure. An increased RV to LV ratio indicates a larger than normal RV and a smaller than normal LV. The RV is perfused during systole and diastole and is very sensitive to systemic hypotension, and ischemia plays a major role in onset of cardiogenic shock. |

## Indications/Contraindications

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| What is the standard treatment for acute DVT? | Oral anticoagulation for 3–6 months |
| What is catheter-directed thrombolysis (CDT)? | Percutaneous introduction of a catheter into the venous system to infuse a pharmacologic thrombolytic agent directly into the thrombus. CDT is more efficacious for acute (fibrin-rich) vs. chronic (collagen-rich) clot. Its use requires inpatient admission and close monitoring in the ICU for any possible signs of bleeding or hemodynamic instability while receiving thrombolytic infusions. |

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| Are percutaneous thrombectomy and CDT stand-alone therapies in the setting of acute DVT? | No, they are recommended as adjuncts to systemic anticoagulation. |
| What are the indications for CDT according to the Society of Interventional Radiology (2014) recommendations? | 1. Acute iliofemoral DVT in ambulatory patients with low bleeding risk and long life expectancy<br>2. Highly symptomatic subacute and chronic iliofemoral DVT<br>3. Acute or subacute IVC thrombosis<br>4. Limb-threatening conditions |
| Why is aggressive therapy recommended for iliofemoral thrombus? | These patients tend to be highly symptomatic and are at high risk for recurrent DVT, post-thrombotic syndrome, and late disability when treated with anticoagulation alone. |
| What are the absolute contraindications to CDT? | 1. Active internal bleeding or DIC<br>2. Recent cerebrovascular event, neurosurgery, or intracranial tumor (<3 mo)<br>3. Absolute contraindication to anticoagulation<br>4. Intracranial trauma within the last 3 months |
| What is the standard treatment for low-risk PE? | Oral anticoagulation for 3–6 months (provoked) or life (unprovoked), similar to acute DVT |

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| What is the standard treatment for intermediate- or high-risk (traditionally "submassive" and "massive") PE? | Systemic thrombolysis, thrombectomy, and CDT are all acceptable options for massive PE treatment. The Society of Interventional Radiology (2018) recommendations state that data are insufficient to support the routine use of CDT for patients with submassive PE. Mechanical thrombectomy is an emerging strategy used to treat massive and submassive PE with promising results, though early data is limited. Mechanical thrombectomy has been considered the primary alternative to surgical embolectomy in patients with submassive to massive PE in whom there is an absolute contraindication for or failure of systemic thrombolysis. In patients with submassive PE, catheter-directed therapy has been shown to decrease the need for treatment escalation and decreases time for clinical improvement but does not increase overall survival. |
| When should a therapeutic inferior vena cava filter be placed? | When a patient has evidence of PE or DVT (IVC, iliac, or femoropopliteal) plus one or more of the following:<br>Absolute or relative contraindication to anticoagulation<br>Complication of anticoagulation<br>Failure to reach therapeutic levels of anticoagulation<br>Propagation/progression or recurrence of DVT or PE while on therapeutic anticoagulation<br>Massive PE with residual DVT in a patient at risk for further PE<br>Free-floating iliofemoral or IVC thrombus<br>Severe cardiopulmonary disease and DVT |

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## Relevant Anatomy

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| What are the proximal deep veins of the lower extremity? | Popliteal, femoral, deep femoral, common femoral, iliac, and IVC. When referring to iliocaval intervention, inflow veins are the femoral, deep femoral, common femoral, and iliac veins. Normalized inflow and outflow are the goal to restore patency, including in cases of PTA or stent. |
| What are the deep veins of the calf? | Anterior tibial, posterior tibial, peroneal, and/or deep muscular veins |
| What are the deep veins of the upper extremities? | Radial, ulnar, brachial, axillary, and subclavian veins |
| Where is the IVC located? | The IVC forms at the confluence of the right and left common iliac veins (L5), travels along the right aspect of the vertebral column, and passes through the central tendon of the diaphragm (T8) to empty into the right atrium. |
| At which pulmonary arterial levels are interventions most efficacious? | Main pulmonary, truncus anterior, interlobar, and basal trunk arteries |

## Relevant Materials

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| What type of catheter should be used during pharmacomechanical CDT? | For pharmacologic CDT, a catheter with multiple side holes, known as an infusion catheter, such as Cragg-McNamara, can be placed across the entire length of the thrombus to allow for infusion of a thrombolytic agent directly within the clot. For mechanical thrombectomy, there are numerous devices available that allow for maceration and/or aspiration of thrombus. Pharmacomechanical therapies involve a combination of both of these methods. |
| What is a common type of infusion system used during pharmacologic CDT? | A coaxial system with a 5- or 6-Fr sheath at the access site and a 5-Fr infusion catheter of appropriate length to reach the site of thrombus is a common system used. |
| Which thrombolytic agents are commonly used during CDT? | Alteplase (tPA) or reteplase (rPA). Relatively low doses of thrombolytic agents are required during CDT in comparison with systemic therapy since the clot is directly bathed in thrombolytics. A commonly used dose of tPA is about 0.01 mg/kg/h or 0.5–1.0 mg/hr in CDT, as opposed to the 0.9 mg/kg/h required in systemic delivery tPA. |
| What is the appropriate activated clotting time for CDT or mechanical thrombectomy? | Patients should be anticoagulated throughout the procedure to achieve an activated clotting time (ACT) of 250–300 seconds or at least 1.5–2 times a baseline ACT. When a baseline ACT is unavailable, it can be assumed to be less than 150 seconds. |

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| What is a benefit of mechanical thrombectomy compared to CDT or pharmacomechanical thrombectomy? | Mechanical thrombectomy avoids the use of a lytic agent and the associated complications. It also obviates the need for ICU stay. |
| What types of stents are used in the iliac veins? | Venous stents have high radial force and are resistant to compression. Wallstents (Boston Scientific; Boston, MA) were traditionally used off-label, but newer, high radial force stents are available, which are FDA approved for iliac vein stenting. |

## General Step by Step

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| What are the preferred access sites during lower extremity VTE intervention? | The posterior tibial or popliteal veins on the affected side are preferred sites to gain access. However, access can be obtained from any deep venous system lower extremity vein or the internal jugular vein. |
| What is the preferred access site for PE intervention? | Generally, the right femoral vein at the groin is the preferred access site in the absence of iliofemoral thrombosis. Some operators prefer internal jugular vein access. |

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| What cardiac precautions should be taken prior to performing pulmonary artery catheterization? | 1. Obtain an EKG and echocardiogram.<br>2. Continuous cardiac monitoring is required in all patients and in select cases; consult with anesthesia consultation may be helpful (need for intubation and general anesthesia in borderline stable patients). Intubation and general anesthesia worsen right ventricular strain and should only be used when absolutely needed (unstable patients and those with progressive respiratory distress).<br>3. After obtaining venous access, right heart and pulmonary arterial pressure should be obtained. Right ventricular end-diastolic pressure should be ≤ 20 mmHg, and pulmonary artery systolic pressure should be ≤ 70 mmHg. Higher pressures have been associated with underlying pulmonary hypertension and increased mortality. In cases of pulmonary hypertension pressure, use of nonionic contrast media and modification of the injection technique, such as performance of subselective injection, can be employed as safety measures. |
| How is the patient positioned on the table in order to gain posterior access? | If accessing from the posterior tibial or popliteal veins, the patient must be prone on the table. |

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| After gaining access into the deep venous system, how is the anatomic extent of thrombus defined? | Venography is performed using a diagnostic catheter to visualize the clot burden under fluoroscopy. Intravascular ultrasound (IVUS) is an adjunctive tool to aid in mechanical thrombectomy and iliac stenting. It is very useful to characterize clot, as well as size and place stents (and ensuring appropriate stent apposition to the wall post-deployment). It can also help ensure clot removal (extent of clot often not fully visualized on venography) as residual clot burden plays a role in reduced inflow and stent patency, as well as persistence and possible worsening of post-thrombotic syndrome. |
| How long are thrombolytic infusion catheters generally kept in place? | For DVT, CDT is typically performed for 24–48 hours. For PE, it is typically performed for 12 hours or less. Certain devices may be placed for dwell for a 30-minute time period, which can be followed by maceration and/or active aspiration of thrombus. |
| If initial infusion-first CDT does not achieve an open vein or prevent immediate re-thrombosis, what adjunctive therapies can be applied? | Balloon maceration, catheter aspiration, thrombectomy device systems, and/or additional thrombolytics can be used to remove residual thrombus. |
| What is the endpoint of therapy? | The endpoint is variable upon the clinical circumstances. General guidelines used to define completion of procedure in various studies include observation of near-complete (> 90%) clot burden reduction on venogram, signs of clinical bleeding, or visible reduction in clot burden on two consecutive venograms with restoration of flow. |

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| In what settings would stenting be appropriate for DVT management? | Stenting would be reasonable to treat obstructive or stenotic lesions in the affected vein with ≥ 50% diameter narrowing or the formation of robust collateral veins, seen as numerous capillary-like vessels that form in response to prolonged obstruction as a bypass. Obstructive lesions in the distal femoral or popliteal veins are often treated with percutaneous transluminal balloon angioplasty without stent placement as stents have a higher likelihood of failure near mobile joints. However, treatment varies greatly between cases. |
| Is CDT commonly used to treat pulmonary embolus (PE)? | Although there are no dual-armed randomized control trials to compare the effectiveness of CDT over systemic anticoagulation for PE treatment, numerous endovascular techniques and devices have been used off-label to treat PE. Small reviews have found faster resolution of the thrombus when treating with CDT than with heparin alone and significant reduction of pulmonary hypertension within 2 hours of treatment. CDT may reduce mortality in PE patients who are hemodynamically unstable but has not been seen to decrease mortality or recurrent PE in stable patients. |
| When should the sheath be removed from the access sites? | Although this is typically up to physician discretion, sheaths should not be removed any less than 1 hour after the final dose of thrombolytics or unfractionated heparin bolus is given. If using manual compression to achieve hemostasis, consider doubling the compression time. For larger mechanical thrombectomy systems and venotomies, figure-of-eight stitch and vascular closure devices can be used. |

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| How long should the patient's treated extremity remain immobile post-procedure? | The patient should remain at bedrest with the accessed limb immobile for 4–6 hours, after which the patient may ambulate as tolerated. Early ambulation is desirable to encourage optimal flow dynamics within the vasculature. |
| When should therapeutic anticoagulation be restarted post-procedure? | Therapeutic anticoagulation should be resumed within 2 hours after sheath removal and access site hemostasis. Unfractionated heparin and low molecular weight heparin are often used to bridge patients to an oral anticoagulation agent until therapeutic levels are reached. The oral anticoagulant is started the same day as sheath removal. For DVT cases, oral anticoagulant should be continued for 3 months to 6 months, depending on presence or absence of PTS. If stents are placed, antiplatelet therapy should be added. |
| What is the follow-up regimen after treating lower extremity DVT? | Follow-up after treatment of lower extremity DVT consists of imaging surveillance often with venous duplex ultrasound and monitoring for clinical signs and symptoms of recurrent DVT or development of PTS. The time frame for follow-up is extremely variable depending upon severity of initial disease and institutional practice often ranging from a few weeks to months post-procedure. For any patient who develops acute symptoms of DVT recurrence, a CT venogram may be considered. |

## Complications

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| What is the most common complication of CDT? | Bleeding is the most common complication of CDT. Large volume hemorrhage is rare, which is generally considered to be that which requires transfusion (about 3–5%) and causes intracranial bleeding or bleeding that leads to fatality. |
| What measures can be taken in the event of bleeding at the venous access site? | Upsizing the sheath and/or compression can be used to control percutaneous bleeding at the access site. If this is unsuccessful, the thrombolytic administration is generally discontinued. |
| What are the most lethal complications associated with CDT? | Intracranial bleeding has been found to be associated with the highest mortality rate in this procedure. |
| What is the risk of intracranial bleeding with CDT? | The absolute risk of intracranial bleeding following CDT is unclear, but generally has been found to be rare in the literature. A pooled analysis of 19 studies discussed in the 2014 quality improvement guidelines for the treatment of lower extremity DVT in JVIR found reported rates to be between 0 and 1% for intracranial bleeding following CDT, in comparison with 3–6% with systemic tPA, and about 0.25–1.5% with standard oral anticoagulation. This data justifies the contraindication for IV tPA use in the treatment of most DVTs. |

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| What is the RIETE score? | It is a score to predict the risk for major bleeding within 3 months of anticoagulant therapy in patients with acute deep vein thrombosis. On multivariate analysis, age > 75 years, recent bleeding, cancer, creatinine levels > 1.2 mg/dl, anemia, and pulmonary embolism at baseline were independently associated with an increased risk for major bleeding. The score is composed of assigning 2 points to recent bleeding, 1.5 to abnormal creatinine levels or anemia, and 1 point to the remaining variables.<br>0 – low risk<br>1–4 – intermediate risk<br>> 4 high risk |
| What are common laboratory guidelines that suggest a poor candidate for CDT? | Hemoglobin < 9 mg/dl, INR > 1.6 before starting warfarin therapy, or platelets < 100,000/mL. It should be noted that these laboratory values are loosely defined and differ based on individual clinical scenarios. |

## Landmark Research

*Attract trial*

Vedantham S, Goldhaber SZ, Julian JA, et al. Pharmacomechanical catheter-directed thrombolysis for deep-vein thrombosis. *N. Engl. J. Med.* 377, 2240–2252 (2017).

- Multicenter analysis with 692 patients comparing rates of post-thrombotic syndrome in patients with acute proximal DVT receiving anticoagulation therapy alone versus anticoagulation plus pharmacomechanical thrombolysis
- Between 6 and 24 months of follow-up, there was no significant difference in the percentage of patients who developed post-thrombotic syndrome (PTS) between the

anticoagulation alone and anticoagulation plus pharmacomechanical thrombolysis groups
- The severity scores of PTS were significantly lower in the pharmacomechanical thrombolysis group
- Pharmacomechanical thrombolysis also reduces early deep vein thrombosis symptoms such as leg pain and calf circumference
- Pharmacomechanical thrombolysis led to less major bleeding (fatal or intracranial hemorrhage) than found in past studies

*CaVenT study*

Enden T, Haig Y, Klow NE, et al. Long term outcome after additional catheter-directed thrombolysis versus standard treatment for acute iliofemoral deep vein thrombosis (the CaVenT study): a randomised controlled trial. Lancet 2012;379:31–8.

Haig Y, Enden T, Grøtta O, et al. Post-thrombotic syndrome after catheter-directed thrombolysis for deep vein thrombosis (CaVenT): 5-year follow-up results of an open-label, randomised controlled trial. *Lancet Haematol* 2016;3:e64-e71.

- Multicenter analysis with 209 patients comparing long term outcome in patients with acute DVT
- This study found a decreased risk of PTS over periods 2 and 5 years in patients receiving catheter-directed thrombolysis as opposed to anticoagulation alone
- The difference in the CaVenT results and Attract trial have been thought to be due to the difference in sample size, geographic and demographic scope of the patients assessed in each study, and the greater use of mechanical therapies in the Attract trial as opposed to longer thrombolytic infusions used in the CaVenT.

*ULTIMA RCT*

Kucher N, Boekstegers P, Müller OJ, et al. Randomized, controlled trial of ultrasound-assisted catheter-directed thrombolysis for acute intermediate-risk pulmonary embolism. *Circulation*. 2014 Jan 28;129(4):479-86. doi: https://doi.org/10.1161/CIRCULATIONAHA.113.005544. Epub 2013 Nov 13.

- 59 patients with acute main or lower lobe pulmonary embolism and echocardiographic right ventricular to left ventricular dimension (RV/LV) ratio ≥1.0 were randomized to receive unfractionated heparin and ultrasound-assisted catheter directed thrombolysis (CDT) or unfractionated heparin alone
- This study found significant reversal of right ventricular dilatation at 24 hours in the CDT group, whereas no improvement in right ventricular enlargement was found in the heparin alone group.
- No major bleeding was found in either group

**Society of Interventional Radiology Position Statement on Catheter-Directed Therapy for Acute Pulmonary Embolism**

Kuo, William T. et al. Society of Interventional Radiology Position Statement on Catheter-Directed Therapy for Acute Pulmonary Embolism. Journal of Vascular and Interventional Radiology, Volume 29, Issue 3, 293–297.

- "The Society of Interventional Radiology (SIR) considers the use of catheter directed therapy (CDT) or thrombolysis to be an acceptable treatment option for carefully selected patients with massive (ie, high-risk) pulmonary embolism (PE) involving the proximal pulmonary arterial vasculature, in accordance with multidisciplinary guidelines. SIR defines acute proximal PE as new main or lobar emboli identified on radiographic imaging within 14 days of PE symptoms."

*SEATTLE II*

Piazza G, Hohlfelder B, Jaff MR, et al. A Prospective, Single-Arm, Multicenter Trial of Ultrasound-Facilitated, Catheter-Directed, Low-Dose Fibrinolysis for Acute Massive and Submassive Pulmonary Embolism: The SEATTLE II Study. JACC Cardiovasc Interv. 2015 Aug 24;8(10):1382–92. doi: https://doi.org/10.1016/j.jcin.2015.04.020.

- 150 patients with acute massive ($n$ = 31) or submassive ($n$ = 119) PE and right ventricular to left ventricular diameter (RV/LV) ratio ≥0.9 on chest computed tomography received catheter directed thrombolytics to assess safety and efficacy of CDT in treating PE in a single arm, prospective, multi-center trial
- The study found that catheter-directed, low-dose fibrinolysis reduced RV dilation, decreased pulmonary hypertension, decreased anatomic thrombus burden, and yielded a lower rate of intracranial hemorrhage in patients with acute massive and submassive PE.

*PERFECT*

Kuo WT, Banerjee A, Kim PS, et al. Pulmonary Embolism Response to Fragmentation, Embolectomy, and Catheter Thrombolysis (PERFECT): Initial Results From a Prospective Multicenter Registry. *Chest.* 2015 Sep;148(3):667–673. doi: https://doi.org/10.1378/chest.15-0119.

- Prospective multicenter study of 101 patients treated with CDT for acute PE to evaluate for safety and efficacy of CDT.
- Clinical efficacy was defined as achieving stabilization of hemodynamics, improvement in pulmonary hypertension, or improved right-sided heart strain.
- Efficacy was achieved in 24 of 28 patients with massive PE (85.7%; 95% CI, 67.3%–96.0%) and 71 of 73 patients with submassive PE (97.3%; 95% CI, 90.5%–99.7%)
- CDT improves clinical outcomes in patients with acute PE while minimizing the risk of major bleeding

*FLARE study*

Tu T, Toma C, Tapson VF, Adams C, et al. A Prospective, Single-Arm, Multicenter Trial of Catheter-Directed Mechanical Thrombectomy for Intermediate-Risk Acute Pulmonary Embolism. JACC Cardiovasc Interv. Volume 12, Issue 9, May 2019. doi: https://doi.org/10.1016/j.jcin.2018.12.022.

- Prospective multicenter study of 106 patients treated with percutaneous mechanical thrombectomy (FlowTriever System) for treatment of acute intermediate-risk PE to evaluate safety and effectiveness
- Primary effectiveness endpoint was defined as reduction in RV/LV ratio. Primary safety endpoint included any major bleeding or device related complication within 48 hours of treatment.
- There was an average 25% reduction in RV/LV ratio with minimal major bleeding or device-related complications (4 patients, 3.8%).
- Mechanical thrombectomy is safe and effective in treatment of PE, as previously found in prior studies.

## Common Questions

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| How long is anticoagulation therapy recommended after initial VTE? | Oral anticoagulation is recommended for a minimum of 3 months after initial VTE. Optimal duration of anticoagulation past 3 months remains unknown and depends on the underlying cause of VTE, if identifiable. |

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| What is the best way to prevent symptomatic PE after DVT treatment? | It is important to maintain adequate anticoagulation before, during, and after any endovascular DVT treatment. It is also important to avoid the use of only mechanical thrombolysis in patients who are eligible to receive pharmacologic thrombolysis as well. Routine placement of IVC filters before or after pharmacomechanical therapy procedures is not recommended. |
| What is the utility of ultrasound surveillance during clinical follow-up? | To monitor for recurrent DVT, valvular insufficiency, or other venous damage |
| When should IVC filter removal be considered? | Patient has no indication for permanent filter.<br>Risk of PE is acceptably low (achievement of sustained appropriate primary treatment or change in clinical status).<br>Patient is not anticipated to return to a high-risk hypercoagulable state for PE.<br>Life expectancy is greater than 6 months.<br>Filter can be safely retrieved.<br>Patient agrees to removal. |
| What resources can be offered to patients post-procedurally to reduce lower extremity swelling? | Patients may be offered the option to wear graduated compression stockings (20–30 mmHg or 30–40 mmHg) daily. Although stockings are generally effective at decreasing lower extremity swelling, they have not been shown to prevent PTS. |
| When should a patient follow up in clinic post-procedure? | The patient should be evaluated in clinic within 1 month of procedure. Proper maintenance of oral anticoagulation is essential to avoid re-thrombosis. |

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# Chapter 22
# Mesenteric Ischemia

**Akhil Khetarpal**

## Evaluating Patient

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| What are the two main categories of mesenteric ischemia? | Acute mesenteric ischemia and chronic mesenteric ischemia. |
| What is the main reason for high morbidity/mortality in patients with acute mesenteric ischemia? | Delay in diagnosis is the main cause of the high morbidity and mortality in patients with acute mesenteric ischemia. The symptoms can often be nonspecific and similar to other causes of abdominal pain, which can lead to misdiagnosis. |
| What are the most common symptoms of chronic mesenteric ischemia? | Chronic mesenteric ischemia is associated with chronic, intermittent postprandial pain and involuntary weight loss. These symptoms should especially heighten your concern for diagnosis of this disease in the elderly or in patients with cardiovascular disease. |

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| What are the most common symptoms of acute mesenteric ischemia? | Acute mesenteric ischemia is associated with severe abdominal pain, typically epigastric pain, out of proportion to physical exam findings. Unfortunately, these symptoms are nonspecific and may be associated with many other common causes of abdominal pain such as bowel obstruction or infection. Acute mesenteric ischemia should always be considered in the differential for patients who present with abdominal pain and also have risk factors for acute mesenteric ischemia. |
| What laboratory tests should be obtained? | A basic laboratory workup including a CBC, BMP, and coagulation profile should be obtained when evaluating patients with mesenteric ischemia. In the case of acute mesenteric ischemia, lactic acid should also be monitored to help determine if there is evidence for bowel ischemia and infarction. |
| What imaging tests should be obtained? | A CTA of the abdomen and pelvis should be obtained to evaluate the mesenteric vessels for evidence of thrombosis, embolism, or spasm. The benefit of CTA is that it also allows you to evaluate for evidence of bowel ischemia (bowel distension, mucosal edema, hyperenhancement, pneumatosis, free air), as well as plan your intervention. In patients with poor renal function or severe iodinated contrast reactions, additional imaging considerations include MRA and Duplex US. |

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| How may arterial intestinal ischemia be differentiated from venous intestinal ischemia on CT? | Underlying atherosclerotic disease may be a clue toward arterial source of disease. Filling defects should be investigated in the arteries and veins, which may suggest thrombus and embolus as etiologies. Lack of mucosal enhancement is more common with arterial ischemia, while "misty" stranding of infiltrated mesenteric fat is seen more with venous ischemia. Increased attenuation of the bowel wall related to submucosal hemorrhage or hyperemia and pneumatosis intestinalis are also features of venous ischemia. |

## High Yield History

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| What are the important elements of the patient history in chronic mesenteric ischemia? | Chronic mesenteric ischemia is a slowly progressing etiology for abdominal pain. Important questions to ask when performing a history in these patients are to determine the chronicity of pain, any associated weight loss, if the pain is specifically postprandial, and if the patient has any history of cardiovascular disease. |
| What are the important elements of the patient history in acute mesenteric ischemia? | Acute mesenteric ischemia has a rapid onset of symptoms. Important questions to ask when performing a history in these patients are to determine the acuity of pain, the quality of the pain (traditional description is pain out of proportion to exam findings), location of pain, and any high-risk predisposing factors for embolic events (e.g., atrial fibrillation) or hypercoagulable state (e.g., factor V Leiden, malignancy, protein C and S deficiency, etc.). |

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| What is NOMI? | NOMI stands for "nonocclusive mesenteric ischemia." This is a form of acute mesenteric ischemia associated with low cardiac output/hypovolemic states. There is no focal obstructive lesion causing decreased mesenteric blood flow but rather an overall diminished volume of the mesenteric vessels. |
| What are the important elements of the patient history in instances of NOMI? | In cases of suspected NOMI, the history should aim at determining potential causes of low cardiac output states. These include a history of heart failure, myocardial infarction, recent hypovolemic state, renal failure, and liver failure. |
| What is an additional non-arterial cause of mesenteric ischemia to be aware of? | Mesenteric venous thrombosis resulting in bowel ischemia is another form of acute mesenteric ischemia to know. Bowel ischemia in this case is caused by venous outflow obstruction due to venous thrombosis instead of an arterial etiology. |
| What are the important elements of the patient history in mesenteric venous thrombosis? | In cases of suspected mesenteric venous thrombosis, the history should aim at determining potential causes of a hypercoagulable state. These causes can include genetic predisposition, medication-induced hypercoagulability, liver failure, and low cardiac output states resulting in venous stasis. |

## Indications/Contraindications

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| What is the most important factor that would necessitate an additional surgical approach to treatment of a patient with acute mesenteric ischemia? | The presence of necrotic bowel contraindicates an endovascular-only approach to treatment of acute mesenteric ischemia. In these cases, the nonviable portion of the bowel needs to be resected. In these cases, open surgical treatment of the affected vessel can be performed, or a hybrid open and endovascular approach to treatment can be used. |
| What are the surgical options for treatment of acute mesenteric ischemia? | The surgical options for treatment of acute mesenteric ischemia include exploratory laparotomy/laparoscopy to evaluate for bowel ischemia followed by mesenteric bypass, endarterectomy, or embolectomy. |
| What are the endovascular options for treatment of acute mesenteric ischemia? | The endovascular options for treatment of acute mesenteric ischemia include aspiration embolectomy, angioplasty, stenting, and catheter-directed lysis. The choice of treatment is dependent on the underlying etiology behind the development of acute mesenteric ischemia. |
| What are treatment options for NOMI? | The treatment of NOMI is aimed at improving the generalized diminished blood flow to the mesenteric vessels. The treatment should employ a strategy of general improvement in volume status and treating the underlying cause of the low cardiac output/hypovolemic state. Catheter-directed vasodilator injection into the mesenteric vascular bed (papaverine) is a described treatment strategy for NOMI. |

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| What are treatment options for mesenteric venous thrombosis? | Treatment strategies in cases of mesenteric venous thrombosis are aimed at both removing the clot burden in the mesenteric venous system and preventing the propagation of further clot. Treatment options include systemic anticoagulation, catheter-directed lysis, and catheter-directed thrombectomy. As in other cases of acute mesenteric ischemia, nonviable bowel should be surgically resected. |
| What is a contraindication to use of thrombolytic therapy? | It is important to know the contraindications to thrombolytic therapy as they are applicable to many disease processes treated in IR. The major contraindications include patients with high risk of bleeding, recent trauma, recent large surgery, recent gastrointestinal bleed, recent stroke, and history of malignancy with associated risk of bleeding from a large malignant mass. |
| What are the surgical options for treatment of chronic mesenteric ischemia? | The open surgical options for treatment of chronic mesenteric ischemia include mesenteric bypass and mesenteric vessel endarterectomy. |
| What are the endovascular options for treatment of chronic mesenteric ischemia? | The endovascular treatment options for treatment of chronic mesenteric ischemia include mesenteric angioplasty and stenting. |

## Relevant Anatomy

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| What general bowel territory does the celiac axis supply? | The celiac axis mainly supplies the stomach and small bowel including the duodenum and jejunum (more proximal portions). |
| What general bowel territory does the superior mesenteric artery (SMA) supply? | The SMA mainly supplies the jejunum (more mid and distal portions), ileum, right colon, and transverse colon. |
| What general bowel territory does the inferior mesenteric artery (IMA) supply? | The IMA mainly supplies the left colon, sigmoid colon, and superior portion of the rectum. |
| What is the source of major collateral pathways between the celiac axis and SMA? | The gastroduodenal artery provides the major collateral pathways between the celiac axis and SMA. |
| What is the name of the major arterial collateral pathway between the SMA and IMA? What is the name of a direct arterial connection between the SMA and IMA? | The marginal artery of Drummond which is found along the mesenteric border of the colon and is formed by terminal branches of the middle colic artery (from the SMA) and terminal branches of the left colic artery (from the IMA). The arc of Riolan is a branch that provides a more direct connection between SMA and IMA, usually connecting a more proximal middle colic branch to a more proximal left colic branch. |
| What is the most common artery involved in cases of acute mesenteric ischemia? | SMA |

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| What is the most common vein involved in cases of mesenteric venous thrombosis? | SMV |
| In cases of mesenteric ischemia caused by vessel stenosis/thrombosis, what portion of the vessel is most commonly involved? | When vessel stenosis/thrombosis is the underlying etiology for mesenteric ischemia, the process typically occurs near the origin/proximal portion of the vessel. |
| In cases of mesenteric ischemia caused by embolic event, what portion of the vessel is most commonly involved? | In embolic etiologies for mesenteric ischemia, the SMA is most commonly involved, and the embolus typically lodges distal to the origin, beyond the first branch points. |

## Relevant Materials

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| What size base catheter is generally suitable for selecting the mesenteric vessels? | A 4 or 5 French curved or reverse curved base catheter is generally used to select the mesenteric vessels. In patients with a very downward-sloping SMA origin, upper extremity access may facilitate selecting the vessel. |
| What are the general categories of devices that may be used in the treatment of chronic mesenteric stenosis/thrombosis? | The general categories of devices used in treating chronic mesenteric ischemia are angioplasty balloons and endovascular stents. |

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| What are the general categories of devices that may be used in the treatment of acute mesenteric embolism/ thrombosis? | Devices used in treating acute mesenteric ischemia are angioplasty balloons, endovascular stents, lysis catheters, and suction/aspiration embolectomy devices. |

## General Step by Step

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| What is the most common access site for mesenteric interventions? | Femoral artery access is the most commonly used access for mesenteric interventions. |
| What are the situations in which upper extremity access is beneficial in performing mesenteric interventions? | Brachial artery or radial artery access is typically used in cases of severely diseased iliofemoral vessels or in cases where the origin of the SMA is difficult to cannulate from the femoral approach, such as in cases of a very downward-sloping SMA origin. Left, as opposed to right, brachial or radial artery access allows the operator to cross over less of the head and neck vasculature along the aortic arch. |
| When is a situation where direct access into the SMA is obtained? | In certain cases, direct puncture into the SMA may be performed, for example, in a case where the patient's abdomen is being surgically explored to resect necrotic bowel and endovascular revascularization is being planned at the same time. |
| What additional support should be placed if endovascular intervention is planned on the mesenteric vessels? | If an intervention is planned, such as stent deployment, a long sheath can be used to add additional support to the catheter/ wire system to stabilize the system prior to intervention, for example, a 6 or 7 French curved sheath. |

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| What are access options in cases of mesenteric venous thrombosis? | The most commonly involved vessel in cases of mesenteric venous thrombosis is the SMV. The SMV drains into the portal venous system which affects the type of available access options. Percutaneous transhepatic, percutaneous transplenic, or TIPS access into the portal vein and SMV can be obtained. |

## Complications

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| What type of monitoring do patients with acute mesenteric ischemia need after intervention with thrombolysis? | Patients with acute mesenteric ischemia should be monitored in the ICU setting if they are undergoing lytic therapy. |
| Why are patients with acute mesenteric ischemia at higher risk of bacterial translocation and/or sepsis? | The decreased blood supply to the bowel results in degradation of the intestinal mucosa resulting in easier translocation of gastrointestinal flora into the bloodstream, thus making close monitoring for signs and symptoms of sepsis critical. |
| What is the major associated complication with the use of thrombolysis? | Bleeding events are the major associated complication with the use of thrombolysis. Patients should be monitored closely in the ICU setting for signs of intracranial and intra-abdominal bleeding. Additional signs of concerning bleeding are access site hematoma, large volume of bleeding at the access site, and drop in hemoglobin. Monitoring of fibrinogen levels is also performed at some centers. If patients are also receiving systemic heparin, PTT values should be checked as well as platelet values to evaluate for heparin-induced thrombocytopenia. |

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| What contrast-related complications should the interventionalist be aware of during endovascular treatment of mesenteric ischemia? | In patients with diminished renal function, there should be monitoring for acute kidney injury. The benefits versus the risks of performing an endovascular intervention should be weighed in patients with diminished renal function. As with all interventions requiring iodinated contrast, any contrast allergy and the severity of the allergy should be clearly understood with premedication administered as clinically warranted. |
| What are rare complications associated with angioplasty and/or stenting of the mesenteric vessels that the operator should be conscious of? | Complications associated with endovascular treatment of the mesenteric vessels to be aware of include vessel perforation, dissection, and stent malposition/migration. |
| What is reperfusion injury? | Reperfusion injury is a paradoxical increase in tissue damage caused by oxidative stress from rapid return of blood supply to tissues after flow is restored in an occluded mesenteric vessel. The mechanism of this injury is multifactorial; however, some proposed causes include tissue damage resulting from oxygen free radicals and cytokine release. |

## Landmark Research

Schermerhorn ML, Giles KA, Hamdan AD, Wyers MC, Pomposelli FB. Mesenteric revascularization: management and outcomes in the United States, 1988–2006. J Vasc Surg. 2009 Aug;50(2):341–348.

- Retrospective review of nationwide database looking at patients who underwent open surgical (16,071 patients) or endovascular treatment (6342 patients) treatment of acute and chronic mesenteric ischemia from 1988 to 2006.
- Lower mortality rate for endovascular treatment of acute and chronic mesenteric ischemia when compared to open surgical treatment.
- Showed that endovascular treatments were appropriate as first-line therapy for appropriately selected patients.
- Inherent selection bias in this retrospective study since patients who necessitated open surgical treatment often were sicker already with more severe states of disease (i.e., needing bowel resection).

Atkins MD, Kwolek CJ, LaMuraglia GM, Brewster DC, Chung TK, Cambria RP. Surgical revascularization versus endovascular therapy for chronic mesenteric ischemia: a comparative experience. J Vasc Surg. 2007 Jun;45(6):1162–71.

- Retrospective analysis of open surgical treatment (49 patients) versus endovascular treatment (31 patients) for chronic mesenteric ischemia at a single center (Massachusetts General Hospital) from 1991 to 2005
- Similar incidence of symptomatic recurrence requiring reintervention in surgical and endovascular groups with a decreased rate of primary patency and primary assisted patency seen in the endovascular group
- Similar incidence of inhospital morbidity and mortality in both groups
- Showed that open surgical and endovascular treatment options should be selectively applied in cases of chronic mesenteric ischemia based on individual patient anatomy and comorbidities

Oldenburg WA, Lau LL, Rodenberg TJ, Edmonds HJ, Burger CD. Acute mesenteric ischemia: a clinical review. Arch Intern Med. 2004 May 24;164(10):1054–62. Review.

- In-depth review of the evaluation and treatment of acute mesenteric ischemia including discussion on the diagnostic and treatment challenges involved with this disease process
- Outlines the pathophysiology and common causes of acute mesenteric ischemia

## Common Questions

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| What is the mortality associated with acute mesenteric ischemia? | The mortality of acute mesenteric ischemia is high and shown to range from 40 to 90%. |
| What vessel is most commonly involved in cases of acute mesenteric ischemia from embolic sources and why? | The SMA is most commonly involved due to its oblique angle of takeoff from the abdominal aorta. |
| What are common risk factors for embolism leading to acute mesenteric ischemia? | Common risk factors for embolic etiologies of acute mesenteric ischemia include cardiac arrhythmias (e.g., atrial fibrillation), cardiac valve disease, history of myocardial infarction, and an aneurysmal disease of the thoracic/abdominal aorta with intraluminal thrombus. |
| What is the common mechanism of thrombotic etiologies for acute mesenteric ischemia? | In cases of acute mesenteric ischemia due to thrombotic etiologies, there is usually superimposed acute thrombosis of a chronically stenosed origin of the SMA and/or celiac axis. |
| What is the common mechanism of thrombotic etiologies for chronic mesenteric ischemia? | Cardiovascular disease risk factors such as hypertension, hyperlipidemia, and diabetes. |

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| What treatment should be instituted after interventions for mesenteric ischemia? | Treatment of underlying cardiovascular risk factors should be initiated including management of hypertension, hyperlipidemia, and diabetes and smoking cessation. In cases of acute mesenteric ischemia, therapeutic anticoagulation and broad-spectrum antibiotic coverage should also be administered. |
| If the patient has a stent placed, what other medications should be considered? | If an arterial stent is used for the treatment of mesenteric ischemia, antiplatelet medications including aspirin and/or Plavix should be considered based on patient risk factors. |
| What kind of surveillance should be performed on patients who have undergone endovascular interventions for mesenteric ischemia? | Patients should undergo routine clinical follow-up to evaluate for recurrence of symptoms as well as compliance with prescribed medications and lifestyle modifications (e.g., smoking cessation). If patients have undergone endovascular stent placement, it is reasonable to perform routine imaging surveillance with duplex ultrasound and/or CTA to evaluate for stent patency and stenosis. |

## Further Reading

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# Chapter 23
# Arteriovenous Malformation (AVM)

**Charles Hua**

## Evaluating Patient

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| According to the ISSVA, what are the five major simple vascular malformations? | Capillary malformation, arteriovenous malformation, arteriovenous fistula, venous malformation, and lymphatic malformation. Mixed variants also exist, and combined vascular malformations are defined as two or more vascular malformations found within the same lesion. |
| What do arteriovenous malformations and arteriovenous fistula have in common? | Arteriovenous malformation and arteriovenous fistula are classified as high-flow lesions. |
| How do soft tissue AVMs present on physical exam? | The mass may be felt with a palpable thrill. The skin may be red and warm to touch. There may be a bruit on auscultation. |

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| How do you differentiate AVMs from low-flow venous malformations on physical exam? | Low-flow venous malformations do not have a palpable thrill. Simple low-flow malformations include venous malformation, capillary malformation, and lymphatic malformation. These low-flow lesions may empty on compression and collapse if raised above the level of the heart. |
| True or false? Brain AVMs are a frequent cause of headaches. | False. Approximately 0.2% of patients with headache and normal neurological exam were found to have an AVM. |
| Name two types of benign vascular tumors as classified by ISSVA and their associated properties. | The two types of benign vascular tumors are infantile hemangiomas, also known as hemangiomas of infancy, and congenital hemangiomas. Infantile hemangiomas appear after birth, usually within the first 2 months of life, and the majority require no specific treatment as they spontaneously involute over a period of years. Propranolol may be used for large hemangiomas that may cause disfigurement and growth disturbance, intrude upon the eye or impact the lips, and prevent attachment during feeding. Congenital hemangiomas are typically fully formed at birth and may rapidly involute (rapidly involuting congenital hemangioma) or not involute (non-involuting congenital hemangioma). Embolization of large hemangiomas may be performed prior to planned surgical resection to minimize the risk of intraoperative bleeding. |
| Where are AVMs typically found? | Liver (41–85%), pulmonary (23–61%), and central nervous system (10%) |

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| What are common findings of AVM on MRI T1 and T2 sequences? | Flow voids are demonstrated on both T1 and T2 sequences. There may be associated muscle atrophy with a lack of mass effect. Of note, phleboliths and calcifications seen in slow-flow venous malformations may also show signal voids, which is demonstrated on all pulse sequences. Draining veins in AVMs may show early enhancement on MR angiography due to shunting. |

## High Yield History

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| What are the common symptoms associated with arteriovenous malformation? | Hemorrhage, pain, ulceration, high-output cardiac failure, pulsatile mass, ischemia, and cosmetic deformation |
| What syndrome predisposes patients to pulmonary AVMs (PAVMs)? | Osler-Weber-Rendu syndrome, also known as hereditary hemorrhagic telangiectasia (HHT) |
| What additional clinical manifestations can be seen in patients with PAVM? | Hemoptysis, headaches, paradoxical embolization, and pulmonary hypertension |
| What percentage of patients with PAVM have HHT? | HHT is an autosomal dominant disorder found in 95% of patients with PAVM. |
| What is the prevalence of HHT? | The estimated occurrence of HHT is 1 in 10,000. However, this is likely underestimated because many cases are asymptomatic. |

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| List two populations that are at greater risk of PAVM complications. | Pregnancy may lead to PAVM growth from the effects of estrogen and progesterone, which increase venous distensibility, resulting in increased vascular volume and cardiac output.<br>The second population at risk of PAVM complications are patients with severe pulmonary hypertension. The elevated vascular resistance can result in increased blood flow through the PAVM. Embolization of the PAVM in patients with severe pulmonary hypertension may alter the hemodynamics (increased preload) and worsen the underlying pulmonary hypertension. |
| What are the clinical diagnostic criteria for HHT? | A consensus of the clinical diagnostic criterion for HHT, known as the Curaçao criteria, is based upon the four findings outlined in Table 23.1. The diagnosis of HHT is "definite" if three criteria are present; "possible or suspected" if two criteria are present; and "unlikely" if fewer than two criteria are present. HHT can also be diagnosed using genetic testing. |

Table 23.1 Curaçao diagnostic criteria for hereditary hemorrhagic telangiectasia

| Criteria | Description |
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| Epistaxis | Spontaneous and recurrent |
| Telangiectasia | Multiple, at characteristic sites, including the lips, mouth, fingers, and nose |
| Visceral lesions | Gastrointestinal telangiectasia; arteriovenous malformations in the lung, liver, and central nervous system |
| Family history | A first-degree relative with HHT |

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| Why do patients develop distal ischemia in extremity AVMs? | Arterial steal phenomenon occurs when a high volume of blood is shunted through the AVM and away from the distal extremity. The peripheral limb beyond the AVM can present with pain, appear pale, or even ulcerate. |
| What type of vascular anomaly are phleboliths associated with? | Low-flow venous malformation |
| What is Klippel-Trenaunay syndrome (KTS)? | A congenital, but not heritable, venous syndrome defined as having at least two of the following: cutaneous capillary malformation, atypical varicose veins, venous malformations, and unilateral limb hypertrophy. |
| What is a patent vena marginalis lateralis? | Also known as the Klippel-Trenaunay vein or the lateral marginal vein of Servelle, it is a persistent embryonic vein ascending along the lateral leg, which lacks normal venous valves and is associated with limb length discrepancy, deep venous system hypoplasia of the affected extremity, chronic venous insufficiency, and venous thromboembolic disease. It is commonly associated with KTS and its presence should warrant further investigation. Most practitioners recommend surgical excision. The persistent sciatic vein is another persistent embryonic remnant associated with KTS and courses along the midline of the posterior thigh. |
| How does Parkes-Weber syndrome (PWS) compare to KTS? | PWS is more rare as compared to KTS and involves high-flow arteriovenous malformations. KTS is associated with low-flow malformations. Both syndromes manifest as unilateral soft tissue and bone hypertrophy. |
| What type of vascular malformation is Maffucci syndrome associated with? | Venous malformation |

## Indications/Contraindications

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| What are indications to treating AVMs? | Cosmetic disfiguration, large mass, severe pain, recurrent bleeding, ischemia, growth disturbance, and high-output cardiac state |
| Why do clinicians choose "watchful waiting" rather than treating extremity AVMs early in their discovery? | Treating AVMs may not be necessary for asymptomatic patients since treatment represents a long-term commitment to the patient and family. Early therapy should only be considered if there is evidence of worsening symptoms, such as shunting, and the patient is willing to undergo the potential for multiple staged sessions. |
| What are the advantages of endovascular therapy over surgical repair? | Surgical resection oftentimes yields poor results because AVMs are often extensive, crossing normal tissue planes. Endovascular embolization allows super-selective catheterization of the feeding vessel; however, cure is not always achievable, and treatment may require multiple procedures. |
| Why is it important to evaluate for severe pulmonary hypertension when embolizing PAVM? | PAVM embolization in someone with severe pulmonary hypertension may further worsen their pulmonary artery pressure, leading to cor pulmonale—right-sided heart failure secondary to increased pulmonary vascular resistance. |
| Why might certain treated vascular malformations worsen (i.e., enlarge)? | Vascular malformations are responsive to stimuli, such as injury or incomplete treatment of the nidus. This may be seen in certain patients who present with a rapid growth of their previously unperceived AVM over a relatively short time period following localized trauma. Therefore, obliterating the nidus should be the therapeutic goal, as incomplete destruction will stimulate vascular growth and possible enlargement of the AVM. |

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| How is worsening right-to-left shunting in PAVM manifested? | Although initially asymptomatic, worsening shunting will develop as arterial hypoxemia, manifested as dyspnea, fatigue, cyanosis, clubbing, and polycythemia. |

## Relevant Anatomy

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| Why might one consider MRI as an imaging modality for pre-procedural workup? | MRI is the mainstay of AVM imaging, especially if there are additional findings that will affect treatment decision. There is no ionizing radiation in MRI, and the high contrast resolution of MRI is used to classify the vascular anomaly and assess the extent of the lesion from the involved anatomy. The three-dimensional dynamic MR angiography sequences provide important information about the abnormal flow hemodynamics. |
| What are the components of an AVM? | The nidus is the central tangle of communicating arterioles and venules with one or more feeding arteries, and one or more draining veins. |
| What is the "nidus" in PAVM? | The PAVM nidus may be a single aneurysmal sac or a plexiform septated connection. They may be acquired or congenital. |
| How do the origin of the pulmonary arteries and bronchial arteries differ? | The pulmonary arteries receive blood from the right ventricle. The bronchial arteries receive blood from the thoracic aorta. PAVMs are abnormally dilated vessels that provide direct communication between a pulmonary artery and pulmonary vein. |
| What is the difference between simple PAVMs and complex PAVMs? | Simple PAVMs have one feeding artery, while complex PAVMs have multiple feeding arteries. |

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| In a patient with known HHT, what is the most likely etiology of a variceal hemorrhage? | This patient most likely has a liver AVM. The clinical presentations of liver AVMs include high-output cardiac failure, portal hypertension, biliary necrosis, portosystemic encephalopathy, and intestinal ischemia/steal syndrome. |
| Why is it important to treat high-flow mesenteric AVMs in a staged fashion? | Treatment of mesenteric AVMs can result in severe portal hypertension as more blood is now being drained through the portal system. |
| What is the most common multivessel supply for pelvic AVMs? | Anterior branches of the internal iliac artery, inferior mesenteric artery, and median sacral artery |
| What is the target of embolization in AVMs? | Elimination of the nidus while preserving flow to normal vessels. Incomplete eradication of the nidus may stimulate growth of the AVM. Treating too proximal may block access to the nidus for future interventions. |
| What is the most common factor that predisposes women to uterine AVM? | It is almost always preceded by an obstetric event (postpartum, postabortion, or dilation and curettage). |

## Relevant Materials

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| Compare the efficacy and toxicity of absolute ethanol versus other embolic agents (n-butyl-2-cyanoacrylate (NBCA) glue and sodium tetradecyl sulfate (STS)). | Ethanol is more effective in obliterating vascular lumens, but more toxic, as well. STS is a sclerosing agent that is less toxic but less effective compared to ethanol. STS is a sclerosing agent that has gained popularity in recent years. NBCA glue has no sclerosant effect but is very useful for vessel occlusion and can significantly slow down the flow. |

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| What is the mechanism of action of absolute ethanol? | Absolute ethanol causes direct tissue toxicity, causing endothelial damage and rapid thrombosis resulting in permanent occlusion. It has a poor safety profile due to its direct intrinsic toxicity and higher likelihood of skin necrosis and neuropathy. |
| What is the purpose of mixing ethiodized oil (Ethiodol) with NBCA glue? | NBCA is an adhesive that rapidly polymerizes upon contact with any ionic solution. Ethiodol is an oil used to provide radiopacity to the glue, as well as slow the polymerization time. Higher ethiodol to NBCA ratio leads to longer polymerization time. Therefore, different ratios of Ethiodol to glue will result in different viscosities and polymerization times, necessitating user experience and careful manipulation of technique depending on the mixture. |
| What is typically used to flush the catheter when using NBCA? | Nonionic, 5% dextrose in water is used to flush the catheter prior to administering NBCA to completely remove ionic substances and allow distribution of the NBCA glue. NBCA polymerizes after coming into contact with ionic substances. |
| How does occluding the dominant venous outflow facilitate NBCA embolization? | Dominant venous outflow occlusion will slow the flow through the lesion and allow the NBCA glue to concentrate at the nidus. |

## General Step by Step

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| What are the available access routes to treat AVMs? | AVMs may be accessed via transvenous, direct puncture, or transarterial routes. Transarterial access to embolize the nidus has been conventionally preferred. If there is no reasonable transarterial access, such as multiple arterioles shunting into a single venous component, or if the remaining feeding arterioles are too small or tortuous to catheterize, then direct puncture of the nidus may allow for effective embolization. In addition to requiring a safe access window for percutaneous direct puncture, there are inherent risks, such as air embolization introduced by the access needle and pneumothorax as a result of transthoracic access. |
| Why should embolization of the proximal portion of the feeding artery be avoided? | Embolization of the proximal portion of the feeding artery without obliterating the nidus will prevent future access to the viable nidus and will promote collateral resupply over time. |
| Is there an ideal embolic agent for all AVMs? | No. There is no ideal embolic agent that encompasses both safety and efficacy. There are a wide range of agents available, including absolute ethanol, liquid-casting agents (NBCA glue), sclerosant (STS), embolization coils, vascular plugs, and ethylene vinyl alcohol copolymers (Onyx). Onyx has weak sclerosant properties and acts through polymerization. Occluding devices (coils, vascular plugs, or microvascular plugs) will benefit fistula-like connections. It is better to embolize the nidus for complex malformations by taking advantage of the blood flow mechanics and using flow dependent embolic agents, such as microspheres, NBCA glue, Onyx, or absolute ethanol. |

| | |
|---|---|
| Why may embolization of the vein in AVMs not be preferred? | The passage of embolic materials into the draining outflow vein can cause nontarget embolization. A situation in which embolization of the draining vein is preferred is when there are multiple inflow arterioles draining into an aneurysmal venous sac. The mechanical occlusion of the venous drainage can then be combined with retrograde injection of the nidus with a liquid embolic or sclerosant. |
| Why do some operators use Swan-Ganz monitoring when using absolute ethanol? | Absolute ethanol is toxic, and escape of the agent into the central circulation has been associated with cardiac arrhythmias, acute pulmonary vasoconstriction, and pulmonary embolization. Due to these risks, some operators prefer careful monitoring using a Swan-Ganz. Additionally, nerve monitoring may be beneficial if the treatment area is within close proximity of a major nerve. |
| Why should treatment be limited to only a few vessels when treating AVMs in the extremity? | Embolizing multiple feeding arteries may lead to peripheral ischemia. Therefore, in addition to eradicating the nidus of the AVM, limited treatment of a few involved vessels will decrease the occurrence of ischemic complications. This may require multiple sessions to accomplish. |
| Where is the ideal site of occlusion for PAVMs? | The goal is to occlude all the feeding arteries, as distal as possible and beyond any significant supply to normal lung. |
| What is an ideal embolic agent for PAVMs? | Mechanical agents, such as coils, are typically recommended. |

## Complications

| | |
|---|---|
| What is an initial treatment consideration for skin ulcers that develop following treatment? | Topical antiseptic cream, such as 1% silver sulfadiazine (Silvadene) and non-steroidal anti-inflammatory drugs. |
| What should one consider if a patient develops shortness of breath and chest pain following embolization of high-flow malformations? | Embolization of the embolic agent or iatrogenic introduction of air into the pulmonary circulation |
| What is a differential consideration in someone with chest pain and fever following PAVM embolization? | Pleurisy is the most common side effect after PAVM embolization, which may develop in 3%–16% of patients several days after the procedure. In patients with delayed pleurisy, a chest radiograph will show infiltrates, which are usually self-limiting. |
| Describe the Spetzler-Martin grading scale for intracranial AVMs. | The Spetzler-Martin grading scale estimates the risk of surgery on the basis of size, neurological eloquence of adjacent brain, and pattern of venous drainage. The grade is based on the total score, with higher grades correlating with increased surgical morbidity and mortality (See Table 23.2). |

Table 23.2 Spetzler-Martin grading scale for intracranial AVMs

| | **Score** |
|---|---|
| *Size* | |
| < 3 cm | 1 |
| 3–6 cm | 2 |
| > 6 cm | 3 |

(continued)

Table 23.2 (continued)

| | Score |
|---|---|
| *Location* | |
| Non-eloquent brain area (anterior frontal or temporal lobes, or cerebellar cortex) | 0 |
| Eloquent brain area (sensorimotor, language, visual cortex, hypothalamus, thalamus, internal capsule, brain stem, cerebellar peduncles, and deep cerebellar nuclei) | 1 |
| *Deep venous drainage* | |
| Absent | 0 |
| Present | 1 |

| | |
|---|---|
| What is a serious complication when treating PAVMs? | An air embolism passing into a PAVM is a serious risk because it can pass directly into the left-sided circulation and into the brain. |
| What is a common side effect following the use of Onyx? | The garlic-like smell that follows Onyx administration is due to DMSO, and it usually dissipates within 2 days. DMSO is slowly injected inside the microcatheter to fill its dead space and prevent direct contact with the bloodstream, thereby preventing its solidification prematurely. |

## Landmark Research

Pollak JS, White RI Jr. Distal cross-sectional occlusion is the "key" to treating pulmonary arteriovenous malformations. *J Vasc Interv Radiol.* 2012;23(12):1578–1580.

| | |
|---|---|
| What are the four ways persistence or reperfusion of an apparently successfully embolized PAVM may occur? | Recanalization of the vessel<br>Growth of a missed or previously small accessory artery<br>Bronchial artery or other systemic artery collateral flow into the pulmonary artery beyond the level of the embolization<br>Pulmonary artery-to-pulmonary artery collateral flow about the occlusion |

Ratnani R, Sutphin PD, Koshti V, Park H, Chamarthy M, Battaile J, Kalva SP. Retrospective Comparison of Pulmonary Arteriovenous Malformation Embolization with the Polytetrafluoroethylene-Covered Nitinol Microvascular Plug, AMPLATZER Plug, and Coils in Patients with Hereditary Hemorrhagic Telangiectasia. *J Vasc Interv Radiol.* 2019 Jul;30(7):1089–1097.

| | |
|---|---|
| What are the persistence rates associated with the coils, AMPLATZER vascular plugs, and microvascular plugs when treating PAVM? | The persistence rates for PAVM with coil embolization are 47%, compared with 15% for AMPLATZER vascular plug, and 2% with the microvascular plug. |

Faughnan ME, Palda VA, Garcia-Tsao G, Geisthoff UW, McDonald J, Proctor DD, Spears J, Brown DH, Buscarini E, Chesnutt MS, Cottin V, Ganguly A, Gossage JR, Guttmacher AE, Hyland RH, Kennedy SJ, Korzenik J, Mager JJ, Ozanne AP, Piccirillo JF, Picus D, Plauchu H, Porteous ME, Pyeritz RE, Ross DA, Sabba C, Swanson K, Terry P, Wallace MC, Westermann CJ, White RI, Young LH, Zarrabeitia R; HHT Foundation International - Guidelines Working Group. International guidelines for the diagnosis and management of hereditary haemorrhagic telangiectasia. *J Med Genet.* 2011 Feb;48(2):73–87.

| | |
|---|---|
| At what diameter feeding artery should embolization of PAVM be considered? | PAVMs with feeding artery diameter of 3 mm or greater should generally be treated. Targeting sub-3 mm feeding arteries may also be appropriate, if technically feasible. It has been shown that paradoxical embolization is independent of feeding artery diameter. |

Cho SK, Do YS, Shin SW, Kim D, Kim YW, Park KB, Kim EJ, Ahn HJ, Choo SW, Choo IW. Arteriovenous malformations of the body and extremities: analysis of therapeutic outcomes and approaches according to a modified angiographic classification. *J Endovasc Ther.* 2006 Aug;13(4):527–38.

Name the four main types of AVMs based on nidus angiographic morphology.

| **Type of AVM** | **Nidus morphologic structure** | **Description** | **Angiographic appearance** |
|---|---|---|---|
| I | Arteriovenous fistula | Three or less arteries shunt into a single vein | Clear communication of the feeding arteries and draining vein |
| II | Arteriolovenous/ plexiform fistula | Four or more arterioles shunt to a single vein | Plexiform |
| IIIa | Arteriolovenulous fistula without dilation | Multiple arterioles communicating with multiple venules | Blush or fine striation |

| Type of AVM | Nidus morphologic structure | Description | Angiographic appearance |
|---|---|---|---|
| IIIb | Arteriolovenulous fistula with dilation | Multiple shunts between arterioles and venules | Complex vascular network |

Mohr JP, Parides MK, Stapf C, Moquete E, Moy CS, Overbey JR, Al-Shahi Salman R, Vicaut E, Young WL, Houdart E, Cordonnier C, Stefani MA, Hartmann A, von Kummer R, Biondi A, Berkefeld J, Klijn CJ, Harkness K, Libman R, Barreau X, Moskowitz AJ; international ARUBA investigators. Medical management with or without interventional therapy for unruptured brain arteriovenous malformations (ARUBA): a multicentre, non-blinded, randomised trial. *Lancet*. 2014 Feb 15;383(9917):614–21.

| | |
|---|---|
| What was the main conclusion of the "A Randomized trial of Unruptured Brain Arteriovenous Malformations" (ARUBA) trial? What were the main controversies of this trial? | Medical management alone is superior to medical management with interventional therapy (i.e., neurosurgery, embolization, or stereotactical radiotherapy) for the prevention of death or stroke in patients with unruptured brain AVMs. There were a higher number of strokes and neurological deficits in patients in the interventional therapy group. The trial was criticized because only 13% of screened patients were randomized in the trial. Majority of the patients that were excluded had potentially more aggressive AVMs that are more representative of brain AVMs in the community. The mean follow-up of 33 months was too short for a disease with a long natural history, favoring the medical management group. Lastly, the small number of patients who underwent microsurgical resection, the gold standard in the interventional arm, biased the trial in favor of medical management. |

Cartin-Ceba R, Swanson KL, Krowka MJ. Pulmonary arteriovenous malformations. *Chest.* 2013 Sep;144(3):1033–1044.

| | |
|---|---|
| Why is it recommended that pregnant patients with significant PAVMs undergo embolotherapy? | There is a high incidence of morbidity (e.g., paradoxical embolism, hemothorax, hemoptysis) and mortality in pregnant patients with PAVM. Embolotherapy in maternal PAVM regardless of feeding vessel size is recommended. Embolotherapy has been shown to be safe and effective after 16 weeks of gestation, and the estimated radiation exposure to the fetus is minimal when performed by an experienced interventional radiologist. |

## Common Questions

| | |
|---|---|
| What are the components of an AVM? | Feeding artery(ies), a nidus, and draining vein(s) |
| What is the most common presenting symptom in patients with HHT? | Epistaxis |
| Where is the most common location for PAVM? | Most PAVMs are seen in the lower lobes. |
| What does ISSVA stand for and who are they? | The International Society for the Study of Vascular Anomalies (ISSVA) is the main organization responsible in classifying all vascular lesions. |
| List the spectrum of organs involved with HHT. | Skin and mucous membranes, liver, gastrointestinal tract, pulmonary, and central nervous system |

| | |
|---|---|
| What is the most common cause of death in patients with HHT? | Stroke, brain abscess, or massive hemoptysis and spontaneous hemothorax |

## Further Reading

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# Chapter 24
# Central Venous Access

**Gaurav Gadodia**

## Evaluating Patient

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|---|---|
| What are important questions in determining access type? | Indication for use<br>Frequency of use (continuous or intermittent)<br>Patient status/length of use (inpatient or outpatient)<br>Patient on or at risk for needing hemodialysis (HD) (i.e., those with chronic kidney disease (CKD) or diabetes)<br>Patient bacteremic or septicemic |
| What primarily determines if a non-tunneled or tunneled line is needed? | Length of therapy |

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|---|---|
| Why is it important to know if the patient has a history of chronic kidney disease (CKD) or diabetes mellitus (DM)? | Dialysis or potential dialysis patients should:<br>Not have peripherally inserted catheters (PICCs or midlines) placed so as to preserve upper extremity veins for future arteriovenous grafts or arteriovenous fistulae (AVGs or AVFs)<br>Have dialysis access separate from other needs of central venous access<br>Have as small as bore catheters placed as able (lower risk for SVC occlusion) |
| What are the recommended lab values to assess for coagulation status pre-procedurally? | INR<br>< 2 for non-tunneled lines and PICCs<br>< 1.5 for tunneled lines and port catheters<br>Platelets<br>Institution dependent, often the goal is > 25–30k.<br>50k is ideal per SIR.<br>If lower, it is recommended to have a unit of platelets infusing during the procedure.<br>aPTT: No consensus recommendation |
| What electrolyte level is important to measure, and why? | Potassium, as it should be corrected prior to procedure if elevated as there is an increased risk of arrhythmia with hyperkalemia |
| What devices should a patient be evaluated for, and why? | Pacemakers, defibrillator/AICDs, and other catheters, as they may decrease the flow or lumen size of the SVC, predisposing to complications |

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| What are important questions to ask the patient while obtaining history? | Prior central venous access procedures and complications<br>Drug allergies<br>Especially to anesthetic, sedation, or contrast (if needed)<br>Active medications, especially blood thinners |

## High Yield History

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|---|---|
| What general types of central venous catheters exist? | Peripherally inserted central catheters (PICCs)<br>Centrally inserted central venous catheters<br>Non-tunneled<br>Tunneled<br>Subcutaneous port |
| In the appropriate setting, why might a PICC be preferred over a tunneled central venous catheter? | PICCs can be removed in an office or nursing home, while tunneled central venous catheters are removed in a procedural setting. |
| In the appropriate setting, why might a tunneled catheter be preferred over non-tunneled access? | Tunneling lowers the risk of infection, along with being more comfortable for patients and less likely to be dislodged, making this type of access more durable and allowing for use in the outpatient setting. |
| In the appropriate setting, why might a subcutaneous port catheter be preferred over a tunneled central venous catheter? | Easier to hide/better cosmetic appearance and ability to swim or bathe |
| What is a distinguishing feature of catheters used for pheresis/dialysis catheters? | High flow rates (dialysis, 400–600 mL/min, at least > 300 mL/min; pheresis, 150–250 mL/min) |

## Indications/Contraindications

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|---|---|
| What are general indications for central venous access? | Therapeutic<br>IV fluids/hydration (may be emergent in settings of resuscitation)<br>Blood products<br>Pressors<br>Plasmapheresis<br>Hemodialysis<br>Antibiotics<br>Ionotropic medications<br>Chemotherapy<br>TPN<br>Other IV medications<br>Diagnostic<br>Central venous pressure monitoring<br>Repeated blood sampling, especially in patients with poor peripheral venous access |

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| What are general indications for the different categories of central venous catheters? | PICCs:<br>Short-term, inpatient or outpatient access<br>Medications, commonly outpatient antibiotics<br>Centrally inserted central venous catheters<br>Non-tunneled:<br>Inpatient only<br>Short-term, temporary access, including for ICU care, or need for dialysis expected to resolve<br>Unstable patients who cannot travel or receive sedation<br>Patients requiring a tunneled catheter but currently with contraindications<br>Tunneled<br>Longer-term access (weeks to months, possibly years) in inpatient and/or outpatient settings<br>Small bore (usually < 7 Fr): general durable central venous access, fluids, most medications including pressors and shorter-term antibiotics<br>Large bore (7 Fr or >): higher viscosity or vesicant fluids like TPN and ionotropic medications, better for blood products, sometimes used for longer-term medications including antibiotics<br>Subcutaneous port<br>Longer-term access (months to years), mostly in outpatient settings, chemotherapy being the most common indication |
| What indications distinguish types of non-tunneled central venous catheters? | Number of lumens needed<br>Need for performance of HD |

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| What are contraindications to non-tunneled central venous catheters? | Absolute:<br>Cellulitis at insertion site<br>Choose another site.<br>Allergy to catheter material<br>Rare, find a catheter with another material.<br>Relative:<br>Central venous thrombosis/occlusion<br>Uncorrectable coagulopathy |
| What are contraindications for placement of tunneled central venous catheters? | Absolute:<br>Sepsis or bacteremia<br>Cellulitis at insertion site<br>May choose another site, or place temporary line at another site until treated and resolves<br>Allergy to catheter material<br>Relative:<br>Venous stenosis<br>Central venous thrombosis/occlusion<br>Uncorrectable coagulopathy<br>Hyperkalemia |
| Is there any indication for an emergent tunneled line? | No, a temporary non-tunneled catheter can be placed for emergent indications. |
| What are indications for removal of a central venous catheter*? | Completion of therapy<br>Malfunction (can try to treat issue or exchange, discussed below)<br>Catheter access or exit site infection (can exchange or re-site, discussed below)<br>Bacteremia (can exchange, discussed below)<br>Sepsis<br>Possible emergent indication for removal<br>*Note: A temporary non-tunneled line or PICC can be placed at the time of removal if needed for clinical management (e.g., for pressors, etc.) |

## Relevant Anatomy

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| What vein is preferred for central venous access and why? | Internal jugular (IJ) due to lower risk of complications (both immediate and delayed) |
| Which side of internal jugular vein (IJV) is preferred for central venous access and why? | Right is preferred over left, as it offers a more direct route to the right atrium and does not need to cross the left brachiocephalic vein<br>Lowers risk of complications (no kink, less risk of fracture) |
| Where does the common carotid artery normally run in relation to the IJV? | Medial |
| Where should the IJV be punctured for central venous access? | 1–5 cm above the clavicle, ideally at the apex of the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle, and the clavicle |
| Why is lower venous access preferred in tunneled lines placed in the IJV? | Less chance of kinking or occlusion |
| What are options if the jugular vein is occluded? | Recanalization of the occluded jugular veins, access via nearby collateral veins including the (often enlarged) external jugular vein, or choosing another site for access |

(continued)

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| What vein is often preferred if the jugular veins are contraindicated? Why is it less preferred than the jugulars? | Subclavian vein, less preferred than jugulars because:<br>Higher risk of immediate complication, especially pneumothorax<br>Higher risk of delayed complication, especially subclavian stenosis causing arm swelling/pain and possible loss of ability to place future AV grafts of fistulae in that arm |
| Where is the subclavian vein in relation to the subclavian artery? | Anterior and inferior to the artery at the level of the first rib |
| How should the subclavian vein be accessed? | Over the anterior aspect of the first rib, lateral to the clavicle.<br>The underlying bone protects against pneumothorax.<br>Infraclavicular approach accesses the vein at the junction of the medial and middle thirds of the clavicle. |
| If a patient has an upper extremity AVG or AVF, which side should jugular and subclavian central venous catheters be placed? | On the side contralateral to the AVG/AVF |
| Where are PICCs placed? | In the upper arm, usually in the brachial, basilic, or cephalic vein |
| What is the ideal final location for the tip of a central venous catheter, and why? | High-flow (dialysis/pheresis) catheters:<br>Proximal right atrium<br>Low-flow catheters (all others, including PICCs):<br>Cavoatrial junction<br>The goal is to place the tips at the locations with the highest flow rates and largest lumen, making clot and occlusion less likely. |

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| What is the approximate location of the cavoatrial junction on AP radiographs? | Two vertebral body units below the carina |
| In general, how can veins reliably be distinguished from nearby arteries? | Veins are compressible, while arteries retain their rounded shape. |
| What other veins outside the chest can be used for central venous access, and what are risks associated with each? | Femoral<br>Higher rate of infection and occlusion than chest, meaning more frequent interventions for catheter maintenance<br>May result in IVC occlusion<br>Direct IVC (translumbar)<br>Malfunction more than chest catheters<br>But similar infection rates<br>IVC occlusion also a possibility<br>Transhepatic IVC or hepatic venous catheters<br>High malfunction rate due to respiratory motion causing liver and thus catheter movement<br>Transrenal<br>Direct right atrial (surgically placed)<br>Does not allow for over the wire catheter exchange<br>Many of these alternate routes also pose increased risk of injury to major surrounding structures due to difficult and deep placement. |
| What structures form the common femoral vein? | Deep femoral and superficial femoral vein |
| Where should the common femoral vein be accessed? | Proximal to the saphenofemoral junction, over the femoral head |

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| Where is the common femoral artery in relation to the CFV? | Lateral and superficial |
| How is the IVC accessed via a translumbar approach? | Posterior approach in a prone patient, to the right of the spine (same side as the IVC/away from the aorta) with a low entry (often through the inferior endplate of L3; A balloon or wire may be inserted into the IVC as a target.) |
| What anatomic obstacles and issues may be present with translumbar IVC access? | Presence of an abdominal aortic aneurysm<br>Anomalous left IVC<br>Right renal artery, which often is posterior to the IVC at the level of L2 |

## Relevant Materials

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| In general, what is the ideal catheter to use? | The smallest bore (lowest risk of venous stenosis), least lumen (lower risk of occlusion as lumens often get smaller in diameter as more are added), and most temporary device possible for the needed indication is the best |
| What materials come in a standard micropuncture kit used to initiate most venous access procedures? | 21-gauge micropuncture needle<br>0.018-in. guidewire<br>Micro-introducer dilator |
| What type of catheter tips exist? | Open tip (end hole)<br>Groshong tip (side hole)<br>Staggered tip |

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| What are examples of common tunneled central venous catheters? | Small bore:<br>Hohn<br>Broviac (mostly used for pediatric patients)<br>Large bore:<br>Hickman:<br>Single lumen: TPN, ionotropic medications, blood products and draws<br>Triple lumen/Trifusion: Stem cell transplant<br>Leonard |
| What are examples of common temporary non-tunneled dialysis catheters? | Quinton: Two lumens with staggered tips<br>Trialysis: Three lumens (two for HD, one power injectable lumen) with staggered tips |
| What types of tunneled dialysis catheters exist? | Shape:<br>Pre-curved<br>Straight<br>Side hole design:<br>Staggered tips are more common:<br>Help to avoid recirculation, but may be prothrombotic<br>Multiple brands<br>At least two lumens<br>Large outer diameter: up to 15.5–16 Fr<br>Length measured "tip-to-cuff": 15, 17, 19, 23, or 28 cm<br>Flow rate > 400 mL/min<br>Coating:<br>Antibiotic-impregnated catheters (minocycline, rifampin)<br>Significantly reduced infection<br>Chlorohexidine and silver impregnated<br>Slight reduction in infection |
| Which patients may antibiotic-impregnated catheters indicated for? | ICU patients |

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| What are the specifications of most port catheters? | Usually single lumen, can be double lumen<br>Open or Groshong tip<br>6.6–9 Fr |
| What does it mean for a catheter to be "power injectable" and why is this important? | Allows for flow of 5 cc/s (pressures up to 600 psi)<br>Can be used for contrast injection for imaging studies |
| What kinds of catheters have Dacron retention cuffs? | Tunneled central venous catheters, including for dialysis<br>Not non-tunneled catheters or ports |
| What are the advantages of valved PICCs and ports? | Lower incidences of infection |
| What valve placement (proximal or distal) is associated with the lowest incidence of infection and occlusive complications? | Proximal |

## General Step by Step

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| Are pre-procedural prophylactic antibiotics generally recommended for placement of tunneled or temporary lines? | No |
| When are pre-procedural antibiotics indicated? | Line exchanges, especially if done for bacteremia<br>Port placements |
| What kind of anesthesia or sedation is generally recommended for each type of procedure? | Local anesthesia only:<br>PICCs and midlines<br>Non-tunneled CVCs<br>Moderate sedation and local anesthetic:<br>Tunneled CVCs<br>Port catheters |

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| How long should common anticoagulation medications be held prior to CVC placement, especially for tunneled catheters or ports? | Clopidogrel (Plavix): 5 days<br>Aspirin 81 mg: No need to hold<br>Heparin drip (gtt): 2 hours<br>Lovenox:<br>Prophylactic (daily): 12 hours<br>Therapeutic (BID): 24 hours<br>Apixaban (Eliquis): 48 hours<br>Rivaroxaban (Xarelto): 24 hours |
| What should be done prior to patient positioning to confirm site selection? | Physical exam of the site for cellulitis, other devices, or other issues<br>Ultrasound the site to ensure vessel patency and favorable anatomy |
| What is ideal patient positioning for attempted IJ and subclavian access? | Supine and slightly Trendelenburg (head down) or legs up<br>Helps increase central venous pressure, distending veins and lowering risk of some complications<br>Head turned to contralateral side.<br>Use of a roll or pillow under the ipsilateral shoulder can help expose the area. |
| How can venous access be confirmed? | Fluoroscopically: The wire should pass below the diaphragm.<br>Ideal, most reliable method<br>Ultrasound: Longitudinal views to ensure placement within the compressible venous system<br>May be inaccurate in patients with aberrant anatomy<br>Pressure manometry<br>May be inaccurate in certain patient positions or in a patient with low pressures (such as in shock) |
| What can make venotomy dilation easier? | Small dermotomy |

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| For tunneled lines and ports, what is the ideal site for the catheter to exit/port pocket? | Approximately 2–3 fingerbreadths (3–6 cm) inferolateral to the clavicle |
| What is the "over-the-wire" method to measure appropriate catheter length? | Place initial guidewire tip in the desired location via fluoroscopy.<br>Clip the wire at the level where it emerges from the sheath.<br>Remove the initial wire with clip in place, ensuring no air embolus can enter the sheath (using a cap or syringe, thumb, or the new wire).<br>Measure from the clip to the end of the removed guidewire, taking into account the amount that was within the sheath outside of the vein, and distance to tunnel exit site as appropriate.<br>Select the catheter of the closest length or trim the catheter to this length, as appropriate. |
| For tunneled catheters, how far into the tunnel should the cuff be placed? | At least 1 cm |
| After tunneling the catheter, what are methods to prevent significant bleeding or air emboli while inserting it into the venotomy sheath? | Use of a peel-away sheath catheter with a valve.<br>If there is no valve:<br>Keep finger on the top of the remaining peel-away sheath while quickly removing the inner dilator and guidewire.<br>Pinch the sheath while inserting the catheter, and have the patient hum to avoid deep inspiration. |

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| After confirming tip placement with fluoroscopy, what are possible methods to close the venotomy site and secure the catheter? | Venotomy site:<br>Manual compression until hemostasis is achieved.<br>For tunneled lines and ports, close with preferred method, for example, absorbable suture, Steri-Strip, or skin glue<br>Catheter securement:<br>PICC:<br>StatLock dressing<br>Tunneled or non-tunneled central venous catheter:<br>Nonabsorbable suture (e.g., 2-0 Prolene)<br>Figure-of-eight, U-stitch, etc. (per preference)<br>Port:<br>Secure port in pocket (optional step) with absorbable or nonabsorbable suture<br>Deeper (dermal) closure:<br>Two to three deep interrupted sutures with braided absorbable suture material (e.g., 3-0 Vicryl)<br>Skin closure:<br>Running subcuticular suture with monofilament absorbable suture (e.g., 4-0 Monocryl, Quill)<br>+/− Skin glue and/or Steri-Strips (with or without subcuticular suture, per preference)<br>Dressing on catheter (including biopatch, etc.) |
| What are recommended methods to lock the catheter to prevent future complication (air embolism, clot formation) before use (may be institutional dependent)? | Normal saline for large-/small-bore CVCs, PICCs, Groshong-tip ports<br>Heparin for all other ports<br>Citrate for dialysis catheters |

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| What are unique features of PICC placement (as compared to CVC placement)? | Positioning: usually nondominant arm if able, abducted, and externally rotated (can ask patient to put the hand behind the head)<br>Use of tourniquet on upper arm |
| How are central venous catheters removed? | Inject local anesthetic along the tract.<br>PICCs and non-tunneled catheters:<br>Cut sutures securing catheter in place.<br>Tunneled catheters:<br>Cut sutures (at the skin, and any deep sutures).<br>Dissect (bluntly, with sharp dissection as needed) around the cuff.<br>Port:<br>Cut the skin over previous port pocket incision, as able.<br>Dissect out port, with care taken to avoid cutting the catheter.<br>Cut sutures securing port into pocket, as needed.<br>Pull the catheter out while patient exhales, with simultaneous manual pressure at the venotomy site.<br>Continue holding pressure over venotomy site and along the tract until hemostasis is achieved.<br>Ensure the entire catheter is removed and intact.<br>Close/dress skin wound with preferred method:<br>For ports: suture pocket closed, usually using the same method as pocket was initially closed during placement |

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| What should be done if the cuff of a tunneled catheter stays in the skin? | Removal, if able without further dissection<br>Otherwise, can usually be left behind, with notification of patient and primary providers<br>Only must come out in the setting of:<br>Cosmetic concerns<br>Failure of tract closure<br>Infection |
| How can the subclavian vein be accessed using fluoroscopy? | Puncture a distal vein in the ipsilateral arm/hand.<br>Inject contrast under fluoroscopy to confirm position of subclavian vein.<br>Use fluoroscopy for puncture (can use roadmap function if available).<br>Advance the needle until blood return, or tip contacts the first rib. |
| How can the subclavian vein be accessed without fluoroscopy? | Place the patient in Trendelenburg.<br>Use a roll or pillow to elevate the patient's thoracic spine, and lower the ipsilateral shoulder.<br>Turn the patient's head away.<br>Puncture the skin 1 cm caudal to the junction of the medial and middle clavicle using palpation.<br>Advance the needle along toward the sternal notch. |

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| How can the common femoral vein be accessed, without sonography? | Place the patient supine with hip in neutral position.<br>Palpate the CFA below the inguinal ligament.<br>Start 1 cm below the inguinal ligament, and 0.5–1 cm medial to the CFA.<br>Palpate or locate the lower third of the femoral head using fluoroscopy.<br>Direct the needle cephalad at a 45-degree angle.<br>Aspirate for return while keeping the CFA localized and going medial to this. |
| What is unique post-procedural care after common femoral venous access? | Bed rest with leg immobile for 3–4 hours |
| How can the IVC be accessed via a translumbar approach? | Place the patient prone or in a left lateral decubitus position.<br>Palpate the right iliac crest and the spinous process superior to it.<br>Insert a long puncture needle about 10 cm to the right of the spinous process.<br>Under fluoroscopy, advance the needle at a 45-degree angle toward the top of the L3 vertebral body, but anterior to this, until blood is aspirated. |
| What is unique post-procedural care after translumbar IVC access? | Bed rest for 4–6 hours |

## Complications

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| What are the overall and major complication rates in image-guided central venous access? | Overall: ~7%<br>Major: ~3% |
| What are possible complications in CVC placement? | Immediate, or procedure-related:<br>Bleeding<br>Pneumothorax<br>Hemothorax<br>Access site hematoma<br>Vein injury or perforation<br>Air embolism<br>Inadvertent arterial injury<br>Procedure-induced sepsis<br>Delayed:<br>Venous thrombosis<br>Phlebitis (especially in PICCs)<br>Venous stenosis<br>Occlusion/fibrin sheath<br>Wound dehiscence<br>Tunnel infection/sepsis<br>Catheter malfunction (can be immediate) |
| What catheter tip positions may cause complications? | Deep (i.e., distal right atrium) placement can cause ectopy and arrhythmia.<br>Shallow (i.e., proximal/mid SVC) placement can increase chance of venous stenosis and catheter malfunction or poor flow due to vessel collapse. |

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| What are some possible site-specific complications? | IJ<br>Carotid artery trauma<br>Pneumothorax (less likely than subclavian access)<br>Subclavian<br>Pneumothorax<br>Hemothorax<br>Chylothorax (especially in left-sided access)<br>Puncture of subclavian artery<br>Femoral<br>Femoral nerve or artery trauma (with higher risk of hematoma and/or pseudoaneurysm than at the neck)<br>Thrombosis of femoral or iliac veins<br>Translumbar IVC<br>Psoas or other retroperitoneal hematoma<br>Puncture of visceral artery or organ, including the aorta |
| Other than immunocompromised patients, which patient group has the highest risk of catheter-associated infection? | Patients on TPN |
| How can an air embolism be managed immediately? | Place the patient in left lateral decubitus position.<br>Keeps the air bubble trapped against the nondependent aspect of the right ventricle and away from the right ventricular outflow tract.<br>Use a catheter to access the bubble under fluoroscopy and suction out. |

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| How can suspected catheter-associated infections be managed? | Non-tunneled CVC:<br>Exchange catheter (over wire, or with new access site)<br>Tunneled CVC:<br>Remove and place temporary access (non-tunneled) as needed.<br>Dialysis catheter:<br>Bacteremic or infected tunnel: exchange catheter over wire +/– new tunnel. If symptoms persist over 36 hours, remove tunneled catheter; place non-tunneled dialysis catheter if needed.<br>48-hour line holiday before replacing<br>Septic patient with any type of catheter: remove emergently; place temporary access as needed. |
| What are possible causes of catheter malfunction (i.e., not flush and/or aspirate)? | Poor positioning (too superficial, causing vessel collapse, or too deep)<br>Tip against vessel wall<br>Catheter kink/fracture<br>Catheter thrombosis<br>Fibrin sheath |
| What is the first step in troubleshooting a malfunctioning line? | Obtain chest X-ray to evaluate if kinked, fractured, or poorly positioned. |
| What can be done if a line is kinked in superficial soft tissues? | Attempt manual reduction; otherwise dermotomy and open reduction if the kinking is superficial versus catheter exchange over wire if it is deeper. |

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| What can be done in a malfunctioning catheter that is not kinked/fractured and is in proper position? | Attempt declotting agents:<br>tPA (alteplase) 2 mg in each port for 30–120 min<br>Repeat x 1 if flow does not improve. |
| What is the next step if declotting agents fail? | Injection study<br>Evidence of fibrin sheath:<br>Strip sheath with a snare*<br>Exchange over wire if this fails<br>No fibrin sheath:<br>Exchange over wire<br>If TDC, a different brand or make of catheter can be attempted<br>*Note: Snares are generally more expensive than catheters, so exchanging may be cheaper. |
| What can be done in the event of CVC occlusion if both thrombolysis and exchange fail? | Resite the catheter, with or without venography if central venous stenosis or occlusion is suspected as the underlying cause. |

## Landmark Research

Sasadeusz KJ, Trerotola SO, Shah H, Namyslowski J, Johnson MS, Moresco KP, Patel NH (1999) Tunneled Jugular Small-Bore Central Catheters as an Alternative to Peripherally Inserted Central Catheters for Intermediate-term Venous Access in Patients with Hemodialysis and Chronic Renal Insufficiency. Radiology 213:303–306.

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| What did Sasadeusz et al. find regarding the placement of tunneled small-bore central venous catheters as compared to PICCs in patients on HD or CKD? | Tunneled catheters are a viable alternative to peripheral catheters in patients with renal issues, and preserve future upper extremity HD access. |

Lund GB, Trerotola SO, Scheel PF, Savader SJ, Mitchell SE, Venbrux AC, Osterman FA (1996) Outcome of tunneled hemodialysis catheters placed by radiologists. Radiology 198:467–472.

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| What are important findings by Lund et al. and Trerotola et al. with regard to the placement of tunneled hemodialysis catheters by interventional radiologists? | Tunneled dialysis catheters placed by interventional radiologists, especially in the right internal jugular vein, had equal or better complication and success rates as those placed by surgeons.<br>Routine use of a single dose of prophylactic antibiotics was found to be unnecessary:<br>Use of antibiotic prophylaxis by Lund et al. was associated with a higher infection rate than the study by Trerotola et al. not using antibiotics, 0.08/100 vs. 0.14/100 catheter days, respectively. |

Ramos ER, Reitzel R, Jiang Y, et al. (2011) Clinical effectiveness and risk of emerging resistance associated with prolonged use of antibiotic-impregnated catheters: More than 0.5 million catheter days and 7 years of clinical experience*. Critical Care Medicine 39:245–251.

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| What did Ramos et al. find in regard to the prolonged use of antibiotic-impregnated catheters? | Significant decrease in central line-associated bloodstream infections in the medical ICU (from 8.3/1000 to 1.2/1000, $p < 0.001$) in patients with catheters coated with minocycline and rifampin, without increased bacterial resistance |

Haas B, Chittams JL, Trerotola SO (2010) Large-bore Tunneled Central Venous Catheter Insertion in Patients with Coagulopathy. Journal of Vascular and Interventional Radiology 21:212–217.

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| What did Haas et al. find in regard to placing large-bore tunneled central venous catheters in coagulopathic patients? | Placement of such catheters is safe even in patients with INR between 1.5 and 2.0, and/or platelet counts between 25,000/dL and 50,000/dL, without need for transfusion of coagulopathic blood products (no bleeding complications found in coagulopathic group of 626 patients). |

Ponec D, Irwin D, Haire WD, Hill PA, Li X, Mccluskey ER (2001) Recombinant Tissue Plasminogen Activator (Alteplase) for Restoration of Flow in Occluded Central Venous Access Devices: A Double-Blind Placebo-Controlled Trial—The Cardiovascular Thrombolytic to Open Occluded Lines (COOL) Efficacy Trial. Journal of Vascular and Interventional Radiology 12:951–955.

Blaney M, Shen V, Kerner JA, Jacobs BR, Gray S, Armfield J, et al. Alteplase for the Treatment of Central Venous Catheter Occlusion in Children: Results of a Prospective, Open-label, Single-arm Study (The Cathflo Activase Pediatric Study). Journal of Vascular and Interventional Radiology. 2006;17:1745–51.

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| What were the salient results of the COOL-1, COOL-2, and CAPS trials regarding the use of alteplase for treating occluded catheters? | COOL-1 and COOL-2:<br>Adult patients<br>74–75% efficacy of one dose of alteplase with an indwelling time of 120 min. (versus 17% after placebo), 88% efficacy of two doses, in catheters occluded up to 14 days (72% in occlusions greater than 14 days)<br>74% cumulative patency at 30 days<br>52% and 84% patency in one and two doses with 30 min. indwelling times, respectively<br>CAPS:<br>Pediatric patients<br>75% patency after one dose of alteplase, and 83% patency after two doses, with indwelling time of 120 min. (53% and 80% with 30-min. dwell times)<br>All demonstrated overall safety of using alteplase for occluded catheters, without increased risk of bleeding or intracranial hemorrhages. |

## Common Questions

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| What is the preferred location for central venous access? | Right internal jugular vein |
| What should be avoided in patients with CKD and DM, and/or those on HD? | PICC and midline placement<br>Placement of catheter on the same side as a maturing AVG or AVF |

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| What is the main factor in deciding between placing a tunneled and non-tunneled catheter? | Length of access<br>Non-tunneled: Days to 1–2 weeks<br>Tunneled: Weeks or longer |
| In general, what is the ideal catheter to use? | The smallest bore (lowest risk of venous stenosis), least lumen (lower risk of occlusion as lumens often get smaller in diameter as more are added), and most temporary device possible for the needed indication is the best. |
| Is there an emergent indication for tunneled central venous access? | No, a non-tunneled central venous catheter can be placed for emergent indications. |
| During placement, what is the best way to confirm access into the venous system fluoroscopically? | Guidewire should pass below the diaphragm. |
| How can an air embolism be managed immediately? | Place the patient in left lateral decubitus position.<br>Keeps the air bubble trapped against the nondependent aspect of the right ventricle and away from the right ventricular outflow tract<br>Use a catheter to access the bubble under fluoroscopy and suction it out. |

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| How can suspected catheter-associated infections be managed? | Non-tunneled CVC:<br>Exchange catheter (over wire, or with new access site)<br>Tunneled CVC:<br>Remove and place temporary access (non-tunneled) as needed.<br>Dialysis catheter:<br>Bacteremic or infected tunnel: exchange catheter over wire +/− new tunnel.<br>If symptoms persist over 36 hours, remove tunneled catheter; place non-tunneled dialysis catheter if needed:<br>48-hour line holiday before replacing<br>Septic patient with any type of catheter: remove emergently; place temporary access as needed. |
| What can be done in a malfunctioning catheter that is not kinked/ fractured and is in proper position? | Attempt declotting agents:<br>tPA (alteplase) 2 mg in each port for 30–120 min<br>Repeat x 1 if flow does not improve. |

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# Chapter 25
# Carotid Artery Stenosis

**Gaurav Gadodia**

## Evaluating Patient

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| How do patients with internal carotid artery (ICA) stenosis usually present? | Asymptomatic, with incidentally detected stenosis (majority) |
| When present, what are symptoms that may indicate ICA stenosis? | Non-disabling or transient ischemic attack (TIA) or transient retinal (amaurosis fugax) symptoms within 6 months |
| What physical exam finding might be present in a patient with carotid stenosis? | Carotid bruit |
| What is the imaging modality of choice for screening for carotid stenosis in patients with symptoms? | Carotid duplex ultrasound |

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| What are possible indications for evaluating *asymptomatic* patients with carotid duplex ultrasonography (along with ASA/ACC recommendation classes and level of evidence)? | Asymptomatic patients with known or suspected carotid stenosis (class I, level of evidence: C)<br>Asymptomatic patients with carotid bruit (IIa, C)<br>Annual assessment of progression or regression of disease and response to therapeutic intervention in patients with atherosclerosis and stenosis of >50% (IIa, C)<br>Asymptomatic patients with symptomatic PAD, CAD, and AAA (IIb, C)<br>Asymptomatic patients with two or more risk factors, including HTN, hyperlipidemia, tobacco smoking, family history of first-degree relative with atherosclerotic issues manifested before 60 years, or family history of ischemic stroke (IIb, C) |
| When does evaluation of ASYMPTOMATIC patients with carotid duplex ultrasonography confer no benefit (class III recommendation to screen)? | Routine screening of asymptomatic patients who have no clinical manifestations of or risk factors for atherosclerosis<br>Routine screening of asymptomatic patients with neurological or psychiatric disorders unrelated to ischemia (i.e., brain tumors, degenerative diseases, infectious or inflammatory conditions, psychiatric disorders, or epilepsy)<br>Routine serial imaging in patients without risk factors |
| Has screening asymptomatic patients with ultrasound been shown to reduce the risk of stroke? | No |

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| Is screening of asymptomatic patients for carotid stenosis recommended per the US Preventive Services Task Force? | No |
| What are the indications for evaluating SYMPTOMATIC patients with carotid duplex ultrasonography? | Initial evaluation in patients with transient retinal or hemispheric neurological symptoms (I, C)<br>Evaluation of patients with focal neurological symptoms corresponding to the territory supplied by the left or right carotid artery (I, C)<br>Can be considered when nonspecific neurological symptoms may be caused by ischemia (IIb, C) |
| What are other indications for evaluation using carotid duplex ultrasonography? | Cervical bruit in an asymptomatic patient<br>Follow-up of known stenosis (>20%) in asymptomatic individuals<br>Vascular assessment in a patient with multiple risk factors for atherosclerosis<br>Stroke risk assessment in a patient with CAD or PAD<br>Stroke in a candidate for carotid revascularization<br>Follow-up after a carotid revascularization procedure<br>Intraoperative assessment during CEA or CAS |

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| What are parameters to evaluate on ultrasonography? | Primary parameters:<br>Peak systolic velocity (PSV) of blood flow in the carotid artery<br>Direct estimation of plaque thickness<br>Secondary parameters:<br>End-diastolic velocity (EDV)<br>Ratio of ICA to common carotid artery (CCA) PSV |
| What are pros and cons of duplex ultrasonography? | Pros<br>No ionizing radiation<br>No contrast needed<br>Often cheaper and more readily available<br>Better for screening/initial evaluation as per above indications<br>Cons<br>Operator variability<br>Uses velocity to estimate degree of stenosis as opposed to direct visualization of stenotic diameter:<br>Degree of stenosis may be over- or underestimated.<br>May overestimate severity of stenosis contralateral to ICA occlusion (increased contralateral velocity may mimic stenosis on sonography).<br>Cannot assess intrathoracic or intracranial lesions<br>May not be able to differentiate between subtotal and complete arterial occlusion<br>Poor evaluation of heavily calcified lesions due to acoustic shadowing |

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| When is CTA/MRA indicated for the evaluation of carotid artery stenosis? | When ultrasonography cannot be obtained or yields equivocal/nondiagnostic results in patients with acute, focal neurologic symptoms corresponding to territory supplied by the left or right ICA (I, C) or in candidates for revascularization (IIa, C)<br>For confirmatory and planning imaging in patients who are candidates for revascularization to evaluate severity of stenosis and identify intrathoracic or intracranial vascular lesions (IIa, C):<br>In practice, MRA is often the test of choice to confirm US findings and further evaluate intrathoracic and intracranial anatomy. |
| What techniques can be used for carotid stenosis evaluation via MRA? | Time of flight (no contrast)<br>Phase-contrast MRA<br>Contrast-enhanced |

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| What are some pros and cons of using MRA for evaluation of carotid artery stenosis? | Pros<br>Anatomic imaging of the aortic arch and major branch vessels<br>Allows for evaluation of both intrathoracic and intracranial vasculatures, unlike US<br>No ionizing radiation<br>Best noninvasive method for evaluating heavily calcified lesions<br>Overall best for assessing plaque morphology including ulceration and risk of thromboembolic event<br>Lower risk of adverse events (including allergy and nephrotoxicity) from gadolinium-based contrast agents used in MRA than from iodinated contrast agents used in CTA<br>Cons<br>Can overestimate stenosis<br>Cannot reliably discriminate subtotal vs complete occlusion<br>Use limited in patients with:<br>Claustrophobia<br>Extreme obesity<br>Certain incompatible implanted devices<br>Depending on type and amount of gadolinium agent used and possible risk of nephrogenic systemic fibrosis (NSF) in some patients with renal dysfunction:<br>Alternatively, time-of-flight MRA technique may be used to evaluate the vessels without the use of contrast. |
| What is a limitation of MRA in the evaluation of carotid stenosis? | Accurate quantification of the degree of endoluminal stenosis due to motion artifact and flow voids |

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| What are some pros and cons of using CTA for evaluation of carotid artery stenosis? | Pros<br>Anatomic imaging of the aortic arch and major branch vessels:<br>Allows for evaluation of both intrathoracic and intracranial vasculatures, unlike US<br>Best noninvasive evaluation of the arterial lumen and degree of stenosis<br>No limitations based on implanted devices<br>Often used in cases with equivocal findings on US and MRA, or with issues excluding MRA evaluation<br>Cons<br>Ionizing radiation<br>Use of iodinated contrast:<br>Higher risk of adverse event including allergy and nephrotoxicity than Gd-based agents used in MRA:<br>Limits use to patients without renal dysfunction<br>Poor evaluation of heavily calcified lesions due to artifact<br>Cannot reliably discriminate subtotal vs complete occlusion<br>Overlying metal including implanted devices and surgical clips may obscure evaluation due to artifact. |

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| What is the gold standard for evaluation of carotid and intracranial atherosclerosis, and why? | Digital subtraction angiography (DSA) of aortic arch, bilateral carotids, and bilateral vertebral arteries including distal to the stenosis<br>Can assess for:<br>Degree of stenosis:<br>Most sensitive method, including in evaluating possibly complete occlusion<br>Intrathoracic and intracerebral disease<br>Aberrant anatomy |
| When is DSA indicated over noninvasive imaging (US, CTA, or MRA)? | When noninvasive testing is inconclusive or not feasible because of technical issues or contraindications in patients with transient retinal/hemispheric neurological symptoms of suspected ischemic origin (IIa, C)<br>For evaluation of the possibility of revascularization when noninvasive testing suggests complete carotid occlusion (IIb, C)<br>Of note: While it is the gold standard for diagnosis, DSA is generally only done during planned endovascular therapeutic intervention. |
| What past medical history is especially important to know pre-procedurally? | History of radiation to the neck<br>History of coronary artery disease (e.g., angina, stents, MIs, CABG) |

## High Yield History

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| What are potential underlying causes of carotid stenosis? | Atherosclerotic plaque (most common)<br>Aneurysm<br>Arteritis<br>Carotid dissection<br>Mass/neoplasm (both benign such as glomus tumor and malignant soft tissue tumors)<br>Radiation necrosis/intimal hyperplasia<br>Vasospasm<br>Cystic medial necrosis<br>Fibromuscular dysplasia (FMD) |
| What are risk factors for carotid stenosis? | Genetic (family history)<br>Hypertension (HTN)<br>Diabetes mellitus (DM)<br>Smoking<br>Hypercholesterolemia |
| What percentage of ischemic strokes are caused by extracranial ICA disease? | 20–30% |
| What is the mechanism of ischemic stroke from ICA disease? | Embolization of atherosclerotic debris or thrombotic material from plaque into more distal cerebral vessels |
| How is carotid stenosis graded (according to 2011 ASA/ACC guidelines)? | Moderate: 50–69%<br>Severe: 70–99% |

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| What velocities on ultrasound correspond to what level of stenosis? | Moderate stenosis (50–69%):<br>PSV of 125–230 cm/s<br>Ratio of ICA to CCA PSV of 2–4<br>End-diastolic velocity (EDV) of 40–100 cm/s<br>Severe stenosis (>70%):<br>PSV > 230 cm/s<br>Ratio of ICA to CCA PSV of >4<br>EDV > 100 cm/s |
| What is the gold-standard treatment for patients with asymptomatic carotid stenosis from atherosclerosis? | Antiplatelet therapy with aspirin, 75–325 mg daily (I, A):<br>If patient has HTN: add antihypertensives to maintain BP below 140/90 (I, A). |
| What is the gold-standard treatment for patients with symptomatic carotid stenosis from atherosclerosis (overall class I, LOE B)? | Aspirin 75–325 mg daily alone<br>Clopidogrel 75 mg daily alone<br>Aspirin plus extended-release dipyridamole (25 and 200 mg BID, respectively):<br>Better than aspirin and clopidogrel together, which shows no benefit within 3 months of symptoms |
| Is there a role for anticoagulation in the setting of carotid artery stenosis? | Anticoagulation with unfractionated or LMW heparin is not recommended in symptomatic patients with carotid stenosis (III, B):<br>Antiplatelet agents are recommended over oral anticoagulants in patients with stenosis with (I, B) or without (I, C) ischemic symptoms. |

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| How should patients with an allergy to aspirin be treated (IIa, C)? | Using $P2Y_{12}$ inhibitors on their own, including:<br>Clopidogrel<br>Prasugrel<br>Ticagrelor<br>Cangrelor |
| What are the major methods of carotid artery revascularization? | Surgical carotid endarterectomy (CEA)<br>Endovascular carotid artery stenting (CAS) |

## Indications/Contraindications

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| What are the indications for revascularization in symptomatic carotid artery stenosis? | Symptomatic patients at low or average risk of procedural complication (<6% risk of major complication or mortality) should undergo CEA or CAS for revascularization if the lumen of the ipsilateral carotid artery is reduced by >70% by noninvasive imaging or >50% by angiography (class: I). |
| When should intervention be undertaken in relation to symptoms? | In cases where revascularization is indicated in symptomatic patients without contraindications, reasonable to do so within 2 weeks of symptom onset (IIa, B) |

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| What are the indications for revascularization in asymptomatic carotid artery stenosis? | Asymptomatic patients should undergo revascularization based on an assessment of comorbidities, life expectancy, and other individual factors (I, C):<br>Reasonable to do CEA in asymptomatic patients with >70% stenosis of the ICA and with low risk of perioperative stroke, MI, or death (IIa, A).<br>CAS may be considered in highly selected patients with asymptomatic carotid stenosis (minimum 60% by angiography, 70% by validated Doppler ultrasound) (IIb, B).<br>Of note: There is no data to prove that this is really better than medical therapy alone. |
| Overall, what is the current recommendations regarding treatment choice in carotid revascularization? | If there are no contraindications, CEA is generally recommended over CAS:<br>Symptomatic patients<br>50–69% stenosis:<br>CEA (I, B)<br>CAS (I, B)<br>70–99% stenosis:<br>CEA (I, A)<br>CAS (I, B)<br>Asymptomatic patients<br>70–99% stenosis:<br>CEA (IIa, A)<br>CAS (IIb, B) |

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| When should CAS be chosen over CEA for revascularization? | When neck or lesion anatomy is unfavorable for arterial surgery (IIa, B), including:<br>History of prior neck surgery or radiation therapy to the neck<br>Carotid dissection<br>Tandem stenosis (carotid and ipsilateral intracranial stenosis)<br>Surgically inaccessible lesion (intrathoracic or intracranial)<br>Tumor encasing the carotid artery<br>Existing tracheostomy<br>Limitation in cross flow circulation:<br>Contralateral carotid occlusion or other disease requiring revascularization<br>Stenosis after completed or attempted CEA within past 31 days<br>In patients with significant cardiac history and risk of periprocedural cardiac event (controversial), including:<br>Congestive heart failure<br>LVEF < 30%<br>Recent MI<br>Significant coronary artery disease<br>Unstable angina<br>Uncontrolled diabetes<br>Recent heart surgery (<6 weeks) |
| In what situations is revascularization not recommended? | <50% atherosclerotic luminal narrowing (III, A)<br>Chronic total occlusion of the target artery (III, C)<br>In patients with severe disability caused by cerebral infarction that precludes preservation of useful function (III, C) |

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| What are absolute contraindications to CAS? | Chronic carotid artery occlusion<br>Allergy to antiplatelet medications<br>Allergy to metals in stent<br>Uncorrectable coagulopathy<br>Incompatible anatomy |
| What are relative contraindications to CAS? | Acute clot within stenosis<br>History of stroke within 6 weeks or prior disabling stroke (modified Rankin scale >3)<br>Recent intracranial hemorrhage<br>Bacteremia/sepsis<br>Immunocompromised state<br>Circumferential or near circumferential calcified lesion |
| What are the indications for re-intervening in patients with restenosis after revascularization? | Reasonable to repeat CEA or perform CAS in patients with symptomatic cerebral ischemia (symptomatic patients) and recurrent carotid stenosis due to intimal hyperplasia or atherosclerosis, using the same criteria as recommended for initial revascularization (IIa, C).<br>Reasonable when duplex ultrasound AND another confirmatory imaging method identify rapidly progressive restenosis that indicates a threat of complete occlusion (IIa, C).<br>In asymptomatic patients with recurrent stenosis, re-operative CEA or CAS may be considered using the same criteria as recommended for initial revascularization (IIb, C), |
| What is a contraindication to reoperation? | Asymptomatic patients with <70% stenosis (class III) |

## Relevant Anatomy

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| What three major branches commonly arise from the aortic arch? | Brachiocephalic trunk (innominate artery), left common carotid artery, and left subclavian artery |
| What is the most common aortic arch anatomic variant? | Common origin of the brachiocephalic and left common carotid arteries (often colloquially called a "bovine arch," which is a misnomer, as it does not normally occur in bovines) |
| Where do atherosclerotic lesions usually occur in the carotid? | At the external/internal carotid bifurcation |
| Where do the external and internal carotid arteries usually bifurcate? | At the level of the thyroid cartilage |
| What is the carotid bulb? | Dilated portion at the origin of the ICA extending for about 2 cm |
| What arteries provide collateral circulation to territories possibly affected by a stenotic ICA? | Ipsilateral external carotid artery<br>Ipsilateral vertebral artery, contralateral ECA, and vertebral artery (via the circle of Willis) |
| What arteries should be evaluated angiographically prior to endovascular revascularization? | Bilateral common carotids and branches (external and internal carotids)<br>Bilateral vertebral arteries |

## Relevant Materials

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| What kinds of catheter can be used for carotid angiography? | 4 or 5 Fr diagnostic catheter (e.g., Bernstein II, Sidewinder II, Multipurpose, Vertebral, Headhunter) |

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| What type of catheter is used for treatment (balloon, stenting)? | 6 Fr (sometimes 7 Fr) guide catheter (e.g., Envoy by Codman Neurovascular or Shuttle by Cook) |
| What types of devices are used for cerebral protection (embolic protection devices, or EPDs)? | Collapsible filters mounted on 0.014 in. guidewires and deployed past the stenosis:<br>For example, Accunet, Emboshield BareWire, FilterWire EX, Angioguard RX, and Spider FX<br>Temporary balloon occlusion devices to occlude the common and external carotid to prevent antegrade or retrograde flow into the ICA:<br>For example, Mo.MA Ultra Device (Medtronic) |
| What can be used if the lesion is too small to cross for a stent device? | Predilation with a small (3–4 mm × 20 mm or smaller) noncompliant PTA balloon or a low-profile cerebral angioplasty balloon like Gateway (Stryker Neurovascular) or Maverick (Boston Scientific Corp.) |
| What type of balloon can be used to dilate the stent? | 4.0–7.0 mm × 20 mm noncompliant PTA balloon (diameter matching that of the normal artery distal to the target lesion) |
| What types of stents are generally used for CAS of the ICA and why? | Self-expandable stents, due to superior crush resistance/ability to regain shape when deformed:<br>Important due to mobility of the neck |
| Where should balloon-expandable stents be used and why? | Common carotid artery ostial lesions:<br>Mobility is limited by thoracic cage (no crushing).<br>It allows for more precise placement. |
| How should stents be sized? | Oversized by 1–2 mm above diameter of vessel in the landing zones |

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| What kind of stents should be used if there is a large discrepancy between the proximal and distal landing zone diameters? | Tapered stents |

## General Step by Step

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| What components of a neurological exam should be completed on the patient pre-procedurally? | NIHSS, modified Rankin scale, and Barthel index of ADLs |
| What can help reduce the risk of stroke intraprocedurally in CAS? | Use of EPD (IIa, C) when the risk of vascular injury from such a device is low |
| What medications should be held pre-procedurally, and why? | Beta-blockers – already potential for bradycardia during manipulation near the carotid bulb<br>Metformin (for 24 prior and 48 hours after) (due to contrast use) |
| What medications should be started prior to the procedure? | Dual-antiplatelet therapy:<br>Clopidogrel (Plavix) 75 mg daily<br>Aspirin (ASA) 81–325 mg daily |
| How long pre-procedurally should these medicines be started? | Elective cases: 5 days prior<br>Emergent cases (within 72 hours of stroke):<br>Loading dose of Plavix 300 mg PO 3–4 hours prior<br>Loading dose of ASA 650 mg PO or PR 3–4 hours |

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| In addition to standard hemodynamic monitoring, what type of monitoring is recommended during CAS, especially with lesions near the bifurcation? | Arterial line, for more sensitive continuous blood pressure monitoring |
| How should anticoagulation be managed intraprocedurally? | Option 1: Unfractionated heparin with target ACT of 250–300 seconds<br>50–70 IU/kg loading dose IV, then titrate<br>Option 2: Direct thrombin inhibitors (especially in patients with HIT)<br>Argatroban:<br>15–30 ug/kg/min infusion with 350 ug/kg bolus followed by 25ug/kg/min infusion<br>Bivalirudin:<br>0.75 mg/kg bolus followed by infusion at 1.75 mg/kg/h for 4 hours, all IV.<br>ACT should be checked 5 min after bolus (give additional 0.3 mg/kg bolus if needed at this time). |
| What medication class can be used if in-stent clot forms during the procedure, and how are they used? | Glycoprotein IIb/IIIa inhibitors (e.g., eptifibatide (Integrilin) and abciximab (ReoPro)).<br>Ensure baseline ACT <200 seconds prior to administration to reduce risk of intracranial hemorrhage. |
| What medicine can be given to reverse effects of heparin activity? | Protamine |

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| How can intraprocedural bradycardia be managed? | Glycopyrrolate (0.2–0.4 mg IV): Can also be given prophylactically in lesions near the bulb to prevent bradycardia<br>Atropine (0.6–1.0 mg)<br>Dopamine (rarely used) |
| What medications can help manage intraprocedural vasospasm? | Nicardipine, intra-arterial (IA)<br>Verapamil IA |
| What IV fluid is best to manage intraoperative hypotension and why? | Albumin helps improve cerebral microcirculation independent of BP. |
| Where is access usually obtained in cases of CAS? | Common femoral artery (preferred). Radial, brachial, axillary, or direct carotid punctures are also used, less often. |
| What is the first step after obtaining access? | Diagnostic angiography (four vessels) |
| What are key points to assess during angiography? | Collateral blood supply via external carotids, posterior circulation<br>Potentially dangerous anastomoses to the ICA from the external/vertebrobasilar system<br>Circle of Willis and intracranial collaterals<br>Lesion length, degree of stenosis, and regional anatomy (landing zone, relation to bulb, tortuosity, ulceration, thrombus, amount of calcifications) |
| What should be attached to the guide catheter after four-vessel angiography and prior to attempts at crossing an ICA lesion? | Pressurized bag of heparinized saline (1 drop/second continuous) |

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| What should be done after accessing the carotid artery with the guide catheter? | Cross the lesion using a 0.014 in. wire, and deploy a cerebral protection device, followed by angiography of the CCA. |
| What if the lesion is too small to cross for a stent device? | Predilate with PTA balloon or low-profile cerebral angioplasty balloon. |
| What are ideal landing zone dimensions for the stent? | 5–10 mm on either side of plaque |
| What should be assessed after stent placement? | Angiography to evaluate for residual stenosis, significant if over 10–15% |
| What should be done if there is significant residual stenosis after stent placement? | Balloon dilation |
| What should be assessed on final angiogram after stent placement and removal of EPD? | Vasospasm<br>Dissection<br>Distal emboli |
| When is it most crucial to monitor the patient for bradycardia? | Anytime there is balloon dilation or other manipulation about the carotid bulb |
| How should tortuous carotid arteries with stenosis be approached? | Use two shorter, overlapping stents to avoid straightening the artery with a longer stent and creating pseudo-occlusion/ kinking |
| For how long after the procedure should antiplatelet therapy be continued? | Dual-antiplatelet therapy with aspirin (81–325 mg qd) and clopidogrel (75 mg qd) should be continued for a minimum of 30 days after procedure (I, C). Aspirin is usually continued indefinitely. |

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| How should patients be managed post-procedurally? | Overnight observation<br>Vitals and neuro exam hourly<br>Bed rest until morning<br>General post-procedural considerations:<br>Hydration.<br>Restart diet.<br>Remove Foley catheter, if placed.<br>DVT prophylaxis. |
| How should the patient be clinically examined after CAS? | Clinical neurological examination for 24 hours after CAS (I, C) |
| How should the patient be followed post-procedurally? | Noninvasive imaging of the extracranial arteries is reasonable at 1 month, 6 months, and annually after revascularization to assess patency and exclude development of new or contralateral lesions (IIa, C):<br>Usually with Doppler, but can use CTA/MRA if anatomic location is too superior for Doppler<br>Can extend surveillance time period once stable over an extended period.<br>Can terminate surveillance if patient no longer a candidate for re-intervention. |

## Complications

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| What are possible acute and intraprocedural complications in CAS? | General arteriographic procedure complications:<br>Allergic reaction to contrast<br>Puncture site trauma/injury including hematoma and pseudoaneurysm<br>Retroperitoneal hematoma (in cases of femoral access)<br>Arterial rupture<br>Arterial dissection<br>Stroke from distal embolization<br>Vagal symptoms including bradycardia and hypotension |
| How can arterial hypotension be managed? | Hydration, with pressor support as needed |
| How can hemodynamically significant arterial dissection be managed? | Immediate stenting, or stop the procedure and manage medically:<br>Heparin bridge to Coumadin, Coumadin for 6 months |
| How can acute thromboembolism be managed? | Intra-arterial abciximab or eptifibatide or tPA<br>Thrombectomy with stent retriever<br>Aspiration thrombectomy<br>Ancillary treatments like colloid infusion/induction of arterial hypertension |
| How can neck hematoma due to venous or arterial rupture be managed? | If minor, reverse heparinization with protamine, usually self-containing.<br>If major:<br>Occlude vessel with balloon catheter.<br>Reconstructive methods like emergent covered stent.<br>Permanent endovascular occlusion of the entire carotid with coils should be considered.<br>Consider emergency surgery. |

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| What patients are at highest risk for venous/arterial rupture? | Patients with history of prior CEA, patients with previous neck irradiation and stricture, and steroid-dependent patients |
| How can reperfusion brain edema be managed? | Mannitol and corticosteroids |
| How can intracerebral hemorrhage be managed? | Consult neurosurgery |
| Why does intracerebral hemorrhage occur? | Reperfusion-related, or delayed transformation of a small ischemic insult |

## Landmark Research

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| What did the NASCET (North American Symptomatic Carotid Endarterectomy Trial-1991) and ECST (European Carotid Surgery Trial-2003) trials find regarding CEA versus medical management alone for symptomatic patients? | Significant benefit for CEA with medical therapy over medical management alone for symptomatic patients with 70–99% stenosis:<br>NASCET also found a benefit for CEA in the moderate stenosis group (50–69%), while ECST did not. |
| What did the ACAS (Asymptomatic Carotid Atherosclerosis Study-1995) and ACST (Asymptomatic Carotid Surgery Trial-2010) trials find regarding CEA versus medical management alone for asymptomatic patients? | Significant benefit for CEA with medical therapy in asymptomatic patients:<br>ACAS: with >60% stenosis versus medical therapy alone<br>ACST: with hemodynamically significant stenosis versus deferring CEA |

## CAS Versus CEA

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| What did the CAVATAS (Carotid and Vertebral Artery Transluminal Angioplasty Study-1999) study find regarding CEA versus endovascular therapy in symptomatic patients with low to moderate surgical risk, and what was a major limitation in the endovascular arm? | Findings:<br>Similar short- and long-term stroke and mortality rates between CEA and endovascular therapy<br>Less other complications in the endovascular arm<br>Similar 30-day and 3-year effectiveness rates<br>Higher restenosis rate in the endovascular arm especially longer term<br>Limitations:<br>No use of cerebral protection devices, as this was prior to their invention<br>Low stenting rate in endovascular arm, mostly just angioplasties |
| What was a unique feature of the SAPPHIRE (Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy-2004) trial, and what were its major findings and limitations? | Unique feature:<br>Only RCT comparing outcomes in high surgical risk patients (both symptomatic and asymptomatic) undergoing CEA vs CAS with an EPD<br>Findings:<br>Favorable results for CAS over CEA at 30 days and 1 year but mostly did not reach significance as study was stopped early for low enrollment.<br>Equally effective at 3-year follow-up in terms of stoke prevention.<br>Carotid artery stenting is non-inferior to CEA in 30-day risk of stroke, death, and MI.<br>There was a statistically significant lower rate of MI in the CAS population at 30 days.<br>Limitations:<br>Controversial as lab findings of cardiac biomarkers were used to diagnose MI, not necessarily EKG findings or symptoms.<br>The study stopped early for low enrollment, so many endpoints did not reach significance. |

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| What were the major findings and limitations of the EVA-3S (Endarterectomy Versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis-2006), SPACE (Stent-Supported Percutaneous Angioplasty of the Carotid Artery Versus Endarterectomy-2006), and ICSS (International Carotid Stenting Study-2010) trials comparing CAS and CEA in symptomatic patients with standard surgical risk? | Findings:<br>Overall: no significant difference in long-term outcomes between CEA and CAS<br>EVA-3S:<br>Terminated early after much higher negative outcome rate in the CAS arm at 30 days<br>However beyond 30 days no difference in adverse outcomes<br>SPACE:<br>Terminated early due to low enrollment<br>No significant difference in outcomes (stoke, death) between CAS and CEA at 30 days or 2 years<br>CAS better for patients <70 years old, and CEA better for patients >70 years old<br>ICSS:<br>CEA was superior to CAS in terms of major negative outcomes (stroke, death, MI) at 120 days follow-up:<br>But at 5 years = no significant difference in major outcome including mortality or disabling stroke<br>Non-disabling stroke was higher in stenting group, but no difference in quality of life or disability.<br>Limitations:<br>Both EVA-3S and SPACE required very minimal operator experience in the CAS arms.<br>EVA-3S:<br>5 prior CAS procedures if unsupervised, 0 if supervised:<br>Trainees with little stenting experience could perform CAS if proctored by qualified operators.<br>SPACE:<br>Operators needed to have a minimum number of successful CEAs.<br>Also needed a minimum number of endovascular angioplasty or stenting procedures in the past, but did not have to be CAS.<br>EVA-3S also used single-antiplatelet medical therapy after stenting, as compared to gold-standard dual-antiplatelet therapy.<br>The use of EPDs was limited, not mandatory, and nonuniform in all three trials. |

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| What was unique about the design of the CREST (Carotid Revascularization Endarterectomy Versus Stenting Trial-2010) trial, and what were its findings? | Design:<br>RCT comparing outcomes of CAS with EPD to CEA in **both** symptomatic patients with >50% stenosis and asymptomatic patients with >60% stenosis at standard surgical risk<br>Findings:<br>CEA arm: significantly higher risk of periprocedural MI<br>CAS arm: significantly higher risk of periprocedural minor/non-disabling stroke<br>Of note, as study continued rates of periprocedural events in CAS arm declined significantly, suggesting a learning curve (no similar change in CEA).<br>At 4 years there was no significant difference in mortality or **overall** stroke rate:<br>Higher rate of stroke in **asymptomatic** patients at 4 years in CAS group<br>No difference in stroke rate at 4 years in **symptomatic** patients<br>Like SPACE, CAS better for patients <70 years old, and CEA better for patients >70 years old |
| What are the overall current findings of pooled research (per a meta-analysis) comparing CEA and CAS? | At 30 days (peri-procedurally):<br>CAS associated with a significantly elevated risk of stroke and death<br>CEA associated with a significantly elevated risk of MI and cranial nerve injuries<br>Beyond 30 days (long-term), comparable findings |

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| What trials are ongoing? | SPACE-2: Two parallel arms of asymptomatic patients with severe stenosis<br>CEA and medical therapy vs medical therapy alone.<br>CAS and medical therapy vs medical therapy alone.<br>Trial currently stopped due to slow recruitment, but data on previously recruited patients ($n$ = 513) continuing to be collected.<br>ACST-2: RCT of asymptomatic patients with severe stenosis comparing CEA vs CAS<br>CREST-2: Two parallel arms of asymptomatic patients with severe stenosis<br>CEA and medical therapy vs medical therapy alone<br>CAS and medical therapy vs medical therapy |
| What are the overall findings from research at this point, informing the above recommendations and guidelines? | Both CAS and CEA can be done with low risk by experienced operators.<br>Long-term outcomes might be the same.<br>CAS better for those with cardiac issues peri-procedurally.<br>While risk of MI is higher in CEA than in CAS, the higher stroke rate in CAS seems to be more detrimental to overall health.<br>CEA favored for more elderly patients.<br>More research needs to be done with uniform use of EPDs, with best medical therapy, and in symptomatic patients with experience CAS and CEA operators. |

## Common Questions

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| Overall, when is carotid revascularization (by CEA or CAS) indicated? | Symptomatic patients with >70% stenosis<br>Patients with <6% risk of perioperative stroke or mortality |

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| When does a patient qualify as "symptomatic" from carotid artery stenosis? | History of non-disabling stroke, TIA, or amaurosis fugax within the past 6 months with ipsilateral carotid artery stenosis |
| Generally, when is CAS indicated over CEA? | In patients with:<br>Significant cardiac history<br>Anatomic contraindications to surgery, such as prior neck surgery or radiation |
| What are the major complications of CAS? | Puncture site trauma<br>Overall higher risk of periprocedural stroke than CEA |
| What is the best screening and follow-up test? | Carotid duplex ultrasonography<br>*Classification of recommendations and level of evidence guide:<br>Class I: Benefit >> risk. Procedure should be performed.<br>Class IIa: Benefit > risk. It is reasonable to perform procedure.<br>Class IIb: Benefit >= risk. Procedure may be considered.<br>Class III: No benefit, or there is harm. Procedure is not helpful or may be harmful.<br>Level A: Data from multiple RCTs or meta-analyses.<br>Level B: Data from one RCT or from non-randomized studies.<br>Level C: Limited data, only case studies or expert opinion. |

## Further Reading

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# Chapter 26
# Renovascular Hypertension

**Gaurav Gadodia**

## Evaluating Patient

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| When should renovascular hypertension (RVH) be suspected? | In patients with:<br>Refractory hypertension under age 30<br>New onset of severe/refractory hypertension after age 50<br>Abrupt worsening of controlled hypertension<br>Hypertension with progressive renal failure<br>Creatinine (Cr) rise over 20% with ACE inhibitors (AKI when put on ACE-I)<br>Secondary hyperaldosteronism and resulting hypokalemia<br>Flash pulmonary edema in patients with preserved LVEF<br>Unilateral small kidney with difference >1.5 cm |

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| What is the definition of refractory hypertension? | Poorly controlled hypertension even on optimal medical management with three antihypertensive medications |
| What is the main underlying cause of RVH? | Renal artery stenosis (RAS) due to atherosclerosis (90%) or fibromuscular dysplasia (FMD) (10%) |
| How do patients with RAS usually present? | Asymptomatic, with RAS incidentally detected during unrelated angiographic imaging |
| What physical exam finding may be found in RAS? | Flank or abdominal bruit |
| What is a possible severe acute presentation of RAS? | Flash pulmonary edema |
| What is the best initial/ screening imaging study for evaluation of RAS? | Doppler ultrasonography (AHA/ ACC class I, LOE: B) |
| What are direct signs of RAS on Doppler? | Peak systolic velocity (PSV) > 180 cm/s<br>Post-stenotic turbulence/bruit<br>Renal artery PSV to aortic velocity ratio > 3.5 |
| What are indirect signs of RAS on Doppler? | Tardus et parvus waveform distal to the stenotic lesion<br>Prolonged acceleration time (> 0.07 seconds)<br>Loss of early systolic peak distal to the lesion<br>Discrepancy in resistive index (RI) before/after the lesion > 0.05 |
| What is another noninvasive imaging modality that can help evaluate RVH when US findings are equivocal? | Computed tomographic angiography (CTA) (I, B) |

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| What is a disadvantage of CTA (especially in this population), and what is an alternative test? | *Disadvantage*: Contrast-induced nephropathy in patient population with a high prevalence of ischemic nephropathy from stenosis<br>*Alternative*: Magnetic resonance angiography (MRA) (I, B) |
| What is the gold-standard test for diagnosing RVH? | Digital subtraction angiography (DSA) (I, B) |
| What are other described diagnostic methods, and their AHA/ACC recommendation class/level of evidence? | Captopril renal scintigraphy (III, C)<br>Selective renal vein renin sampling (III, B)<br>Plasma renin activity (III, B)<br>Captopril stimulation test (III, B) |

## High Yield History

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| About what percentage of patients with HTN have underlying RAS? | 5% (0.5–10%) |
| What is the underlying pathophysiology of RAS causing RVH? | Decreased renal perfusion ➔ renin release by juxtaglomerular cells ➔ activates angiotensin II, causing:<br>Efferent arteriole constriction to increase renal perfusion<br>Systemic hypertension<br>Aldosterone elevation leading to sodium/water retention and diastolic dysfunction |
| What is the definition of hemodynamically significant RAS (ACC/AHA and ACR/SIR)? | 10% or greater mean translesional pressure gradient (and/or SBP gradient > 20 mmHg or > 10 mmHg mean gradient difference) |

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| What lab abnormality is associated with a worse prognosis in RVH? | Creatinine > 3.0 |
| What are the demographics of RAS caused by atherosclerosis? | Older men |
| What are the demographics of FMD? | Women aged 30–50 years old |
| What subtype of FMD is associated with HTN? | Medial subtype, with intimal and adventitial subtypes being much less likely to cause HTN (< 15% combined) |
| What is the characteristic appearance of FMD? | "Beading" of the artery due to alternating stenoses and aneurysms |
| What findings are associated with FMD? | True and dissecting aneurysms<br>Arteriovenous fistulas |
| What is another differential for RAS? | Noninflammatory vasculitis |
| What is the most common noninflammatory vasculitis subtype? | Medial fibroplasia |
| How is this treated? | Balloon angioplasty. Only pursue stenting if angioplasty fails or there are complications. |
| What are uncommon etiologies for RVH? | Renal artery aneurysm, Takayasu arteritis, neurofibromatosis, Iatrogenic or traumatic injury causing dissection, vessel injury damaging the intima causing thrombosis, retroperitoneal tumor encasement/compression, Williams syndrome, segmental arterial mediolysis, and midaortic syndrome |

## Indications/Contraindications

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| What is the gold-standard initial treatment for RVH? | Medical management including (class I, A):<br>ACE inhibitors<br>Angiotensin receptor blockers<br>Beta-blockers<br>Calcium channel blockers |
| When medical management fails, what are invasive treatment options? | Surgical or endovascular revascularization |
| What arteries are used for bypass in surgical revascularization? | Splenic artery for the left kidney and hepatic and gastroduodenal artery (GDA) for the right |
| When is surgery indicated over endovascular treatment? | FMD with segmental artery involvement or with macroaneurysms (I, B)<br>Atherosclerotic RAS with multiple small renal arteries or early primary branching of the main renal artery (I, B)<br>Atherosclerotic RAS with pararenal aortic reconstructions (e.g., after prior AAA treatment)<br>Refractory/recurrent RVH after previous endovascular treatment |
| How is RVH treated endovascularly? | Atherosclerotic RAS:<br>Angioplasty and stenting<br>May be treated with angioplasty only if non-ostial location<br>FMD: Angioplasty only |

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| What are the indications for renal vascular imaging or angiography (RAS screening) based on patient presentation (per the SIR, with ACA/AHA classes and levels of evidence)? | Onset of HTN before age of 30, especially without family history (I, B)<br>Recent onset of significant HTN after the age of 55 (I, B)<br>Accelerated, resistant, or malignant HTN (I, C)<br>Sudden (flash) or recurrent pulmonary edema, especially with azotemia (I, B)<br>Renal failure of uncertain cause, especially with a normal urinary sediment and less than 1 gram of protein per daily urinary output<br>Coexisting, diffuse atherosclerotic vascular disease, especially in heavy smokers<br>Acute renal failure precipitated by antihypertensive therapy, particularly angiotensin-converting enzyme (ACE) inhibitors or angiotensin II receptor blockers (I, B)<br>Idiopathic unilateral atrophic kidney (size difference >1.5 cm) (I, B)<br>Unexplained renal failure (IIa, B) |

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| What are potential indications for revascularization in RVH caused by RAS (ACC/AHA classes and levels of evidence)? | Asymptomatic patient with hemodynamically significant RAS (IIb, C)<br>Hemodynamically significant RAS with (IIa, B):<br>Accelerated HTN: sudden worsening of previously controlled HTN<br>Resistant HTN: HTN that cannot be controlled (< 140/90, or SBP < 160 in patients over 60) on a maximally dosed triple-drug regimen including a diuretic<br>Malignant HTN: HTN with end-organ damage including left ventricular hypertrophy, congestive heart failure, visual or neurologic disturbance, or advanced retinopathy<br>HTN with an unexplained unilateral small kidney<br>HTN with intolerance to anti-HTN medications<br>Progressive CKD with (IIa, B):<br>Bilateral RAS<br>RAS to a solitary functioning kidney<br>Chronic renal insufficiency with unilateral RAS (IIb, C)<br>Hemodynamically significant RAS with cardiac destabilization syndrome (I, B), including:<br>Recurrent, unexplained congestive heart failure<br>Sudden, unexplained pulmonary edema<br>Hemodynamically significant RAS and unstable angina (IIa, B)<br>Acute, symptomatic, idiopathic renal artery dissection with new flank pain, hematuria, or accelerated HTN without underlying connective tissue disorder or other pathology (per ACR/SIR. No AHA/ACC recommendation) |

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| What are absolute contraindications to renal revascularization? | Hemodynamically nonsignificant stenosis |
| What are relative contraindications to renal revascularization? | Long-segment total occlusion<br>Severely diseased aorta, as there is increased risk of embolization of the atheroma |
| When is stent placement indicated over balloon angioplasty? | Stenotic ostial atherosclerosis (within 1 cm of aortic lumen)<br>Restenosis after prior treatment<br>Postoperative (renal bypass, transplanted renal arteries) stenosis<br>Highly eccentric renal artery stenosis<br>Acute failure or complication of PTA including:<br>Vessel recoil with possible collapse<br>Complex dissections not responding to prolonged reinflation<br>esidual stenosis > 30% or residual pressure gradient > 10% MAP<br>Rupture or perforation (use covered stent) |
| How can you treat in-stent restenosis? | Options include PTA and re-stent. |
| When is stent placement relatively contraindicated? | Branch vessel disease<br>Stent placement that would traverse renal artery branches<br>Lesion length > 2 cm<br>Renal artery diameter < 4 mm (can use coronary-sized stent)<br>Unfavorable renal anatomy, without enough vessel length distal to proposed stenting to allow for future surgical bypass if needed<br>Diffuse intrarenal vascular disease<br>Noncompliant lesion<br>Kidney size < 7 cm |

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| What are indications for renal vein renin sampling? | To determine which patients may benefit from revascularization<br>To determine the physiologic significance of RAS |
| What are contraindications to renal vein renin sampling? | Patients who are not candidates for revascularization<br>Patients with occlusions of the renal vein/ICV or IVC filters |
| What can hinder accurate interpretation of renal vein renin sampling results? | Patients on chronic ACE inhibitors or beta-blockers not able to be safely taken off medication |

## Relevant Anatomy

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| How many renal arteries do patients commonly have? | One per side |
| What are important variations to normal renal artery anatomy? | Accessory renal artery arising from the aorta (can be unilateral or bilateral)<br>Early branching of the renal artery, within 1 cm of the aorta |
| What lesion location lends more to atherosclerosis over FMD? | Ostial location (proximal third) |
| Which underlying cause is more likely in bilateral RAS, atherosclerosis or FMD? | Atherosclerosis |

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| What is the characteristic location of FMD? | Usually involving the mid to distal portion (the proximal artery may be involved, but rarely in isolation). This is often unilateral, with a preponderance for the right side over the left. |

## Relevant Materials

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| What kind of sheaths should be used for renal arterial interventions, especially in cases of atherosclerotic RAS? | Longer arterial sheaths (20–30 cm) are best as they help decrease the potential for plaque disruption during exchanges and manipulations. A 40 cm Flexor Ansel Sheath (Cook Medical) is often used during intervention. |
| What kind of wire and catheter can be used to cross an atherosclerotic RAS lesion? | Soft atraumatic wire (e.g., Bentson) and recurved catheter (e.g., Sos Omni Selective (AngioDynamics) or Simmons) |
| What balloon diameter should you use for renal arterial angioplasty? | Approximately 1% larger than estimated normal vessel diameter (not size of post-stenotic dilation) |
| What kind of stent is best for RAS, especially for ostial lesions, and why? | Balloon-expandable metallic stents, due to precision of placement |
| How do you choose stent size? | Adequately covers the lesion in length and with diameter matching normal (pre- and post-stenotic) vessel diameter (usually 1–2 cm length, 4–8 mm diameter) |
| What type of guidewires should be avoided and why? | Hydrophilic wires may cause perforation or dissection and may not provide enough support for stenting, though can be used to atraumatically cross lesions and then exchange for a working wire. |

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| What do you use to measure a pressure gradient? | Lowest profile pressure wire (such as 0.014 in.) |
| What kind of catheter is ideal for renal vein renin sampling? | 5 Fr. Cobra 2 catheter with a side hole made at the distal tip 2–3 mm from end hole |
| What catheters can help access the renal vein in difficult sampling cases? | Sidewinder or other recurve catheters |

## General Step by Step (DSA and Endovascular Revascularization)

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| Per the SIR, what are ideal coagulation parameters pre-endovascular intervention? | INR < 1.5<br>Platelets: Transfusion if below 50,000/L |
| Are prophylactic pre-procedural antibiotics recommended for endovascular revascularization? | No |
| How should you manage patients with chronic kidney disease (CKD) or risk factors for AKI or CKD (e.g., DM, MM, dehydration) periprocedurally? | Hydrate overnight with 0.45% saline with sodium bicarbonate at a rate of 100–150 cc per 4–12 hours.<br>At least 1 hour of hydration.<br>Use 30–50% diluted iodinated contrast or non-iodinated contrast such as carbon dioxide. |
| How should you manage a patient's hypertension prior to a renal revascularization procedure? | Discontinue long-acting antihypertensives and manage with short-acting antihypertensives instead, as able. |

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| Where should vascular access ideally be obtained? | Femoral, preferably on the right |
| Where should you obtain access if the patient has distal aortic occlusion or unfavorable renal artery angle? | Left brachial access, or radial access |
| What is the next step after obtaining access? | Diagnostic angiography starting with a flush aortogram and then selective renal angiogram |
| What is the best projection/ view angle for aortic disease and ostia? | LAO, about 20° for the right renal arter<br>LAO, about 5–10° for the left artery |
| If disease is bilateral, on which kidney should you start intervening? | Start with the larger kidney, as disease is usually less severe and if cannot successfully treat that one, likely will not be able to treat either (this can also allow for a two-stage therapy, and at least help the patient in the interim). |
| What are techniques to decrease risk of embolization especially from atherosclerotic aorta? | "No touch" technique:<br>0.035 j wire placed alongside the guidewire inside guide catheter that is in the suprarenal aorta to lift the catheter tip off of the aortic wall<br>"Sos flick" technique:<br>Soft atraumatic guidewire 1–2 mm out of a SOS Omni Selective catheter, advance up the aorta with wire sticking out toward the direction of renal artery want, will "flick" in. |
| How do you prevent spasm of the renal artery prior to guidewire insertion? | Intra-arterial (IA) nitroglycerin (100–200 micrograms) |

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| How can you provoke a pressure gradient to assess for need for revascularization? | 50 ug/kg dopamine IA (this has the best evidence)<br>100–200 ug nitroglycerin IA<br>30–40 mg papaverine IA<br>1 mg isosorbide dinitrate IA |
| What do you do in the event of occlusive dissection or perforation? | Place a covered or uncovered stent. |
| How do you prevent thrombosis once you have crossed the stenosis? | Heparin IV: administer a 5000 unit bolus, followed by infusion of 750–1000 U per hour. |
| What is the target activated clotting time (ACT) for stenting/intervention? | 2.5× baseline (~ 300+ seconds) |
| What is the target ACT when removing the femoral sheath at the end of the procedure? | < 180 seconds |
| How do you position the stent if the lesion is ostial? | Place stent to extend 1–2 mm into the aortic lumen. |
| How much stent overlap should there be if you are stenting in series (multiple stents)? | 2 mm |
| How long do you keep the balloon inflated for angioplasty? | For 1 minute (or until/if patient has severe pain) |
| What do you do after completing angioplasty/ stenting? | Angiogram, avoiding recrossing the stenosis |
| What do you do if the angiographic result is not good or a significant pressure gradient still exists? | Upsize balloon to 1 mm larger than previous; repeat until good result. |

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| What must you do if endovascular revascularization has failed, and/or patient is planned to undergo surgical revascularization? | Angiography of possible donor vessels, most importantly the celiac access |
| What is the imaging modality of choice for follow-up after stent placement? | Renal Doppler ultrasound |
| What is the definition of technically successful endovascular renal revascularization (ACR/SIR)? | < 30% residual stenosis and a pressure gradient less than the selected threshold for intervention (< 10% and/or mean SBP gradient < 20 mmHg or 10 mmHg mean gradient difference) |
| What is the overall technical success rate of endovascular revascularization with stent placement in atherosclerotic RAS? | 95% or greater |
| What labs should you monitor for 24 hours after the procedure? | Serum creatinine and BUN |
| How long should you monitor BP for? | At least 24 and up to 48 hours |
| What should you do if BP drops below normal levels? | Infusion of normal saline IV |
| What should you do if BP increases during or after the procedure? | Administer an ACE inhibitor such as captopril.<br>Use other short-acting medicines if severely elevated. |
| Do any medications need to be continued post-procedurally? | If a drug-eluting stent was used, then aspirin 81 mg or another antiplatelet medicine must be used for 6 months. |

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| When do most recurrences happen? | Within the first 8 months |
| What is the failure rate of primary stent placement requiring re-intervention? | ~11% |
| What is the failure rate of repeat intervention on in-stent stenosis? | ~20% |
| What are the risk factors for restenosis after stenting? | Stents dilated to less than 6 mm<br>Female sex<br>Age greater than 65 years<br>Smoking |
| What is the technical success rate of angioplasty in FMD? | 95% or greater |
| What is the primary patency of angioplasty-treated FMD? | 69% at 4 years |
| What is the clinical response to angioplasty in patients with hypertension due to renal artery FMD? | 22–39% cured and 31–59% improved/partial response |
| What are the definitions of clinical evaluation after revascularization? | *Cured*: BP< or = 140/90 without meds<br>*Improved/partial response*: diastolic BP decreased by 10–15 mmHg or greater on the same or less meds, OR decreased in diastolic BP by 10–15 mmHg without medications (normal with meds)<br>*Stable*: diastolic BP within 15 mmHg on the same or less meds<br>*Failed*: diastolic BP unchanged on the same or less meds |

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| What are the definitions of evaluating renal dysfunction after revascularization? | *Improved*: decreased serum creatinine by 20% or more over baseline<br>*Stable*: creatinine within 20% of baseline<br>*Failure*: elevation of creatinine of 20% or more over baseline |

## Step by Step (Renal Vein Renin Sampling)

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| How should you manage patient's hypertension prior to renal vein renin sampling? | Off all antihypertensives for 2 weeks prior; most importantly, off beta-blockers and ACE inhibitors. |
| How can you increase the accuracy of renal vein renin sampling? | Captopril 60–90 minutes before procedure (increases renin secretion on affected side)<br>Sodium depletion |
| What is a primary difference between renal vein renin sampling and renal endovascular revascularization, procedurally? | Venous puncture as opposed to arterial puncture |
| Where does left renal vein renin sampling occur? | Beyond the orifice of the left gonadal vein |
| Where does right renal vein renin sampling occur? | Close to the IVC, no gonadal vein drainage to worry about |
| Where do you obtain control samples from? | The infrarenal IVC |
| Can you use contrast in renal vein renin sampling? Why/why not? | No, contrast affects the production of renin, potentially altering the results. |
| What is the protocol for obtaining samples? | Obtain as closely together as possible (within 20 minutes), and transport to lab on ice. |

## Complications

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| What is the overall mean complication rate of endovascular intervention? | ~14% |
| What is the most common type of complication? | Groin hematoma and puncture site trauma including hemorrhage, rupture, inadvertent venous puncture, and arteriovenous fistula (3–5%) |
| What are some possible complications at the angioplasty site? | Local thrombus<br>Nonocclusive dissection (caused by guidewire or angioplasty)<br>Arterial rupture |
| What is a risk of having balloon up too long or taking too long to deflate the balloon? | Thrombus formation and possible vessel occlusion |
| How do you manage local thrombus without significant dissection or vessel perforation? | Trial of local intra-arterial thrombolysis: 5 mg t-PA over 30 minutes, followed by 0.5 mg per hour for up to 24 hours |
| How do you manage arterial rupture? | Gently inflate balloon across the tear to tamponade.<br>Deploy covered stent, as needed. |
| How do you manage non-flow-limiting dissections? | No management needed, common occurrence |
| How do you manage flow-limiting dissections? | Prolonged reinflation of a 1 mm undersized balloon or deployment of a covered stent |
| Which patients are at higher risk of vessel rupture in renal angioplasty? | Those on chronic steroid therapy |
| What are other risk factors for general complications and recurrence? | Current smokers<br>Untreated hyperlipidemia |

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| What are some possible extra renal complications? | Emboli to extremities<br>Puncture site complications<br>Myocardial infarction |
| What is the rate of major complication (requiring surgery or prolonged hospitalization)? | 3–11% (vs. 20% for surgery) |
| What are major complications, and their incidence? | Worsening of renal function due to contrast and/or multiple small infarctions by microemboli (3–5%)<br>Occlusion of renal artery (2–3%)<br>Segmental infarction and perinephric hematoma (1–2%)<br>Need for surgical intervention such as nephrectomy and salvage (2%)<br>Death (1%) |
| What is the 30-day mortality, and what are the causes? | < 1%. Caused by renal artery perforation, cholesterol embolization, ARF, and arterial access above the inguinal ligament with subsequent bleed |
| What is the 30-day surgical mortality? | Up to 5% |
| Which patients have a higher rate of complication with revascularization: those with FMD or atherosclerotic stenosis? | Atherosclerosis |
| What has been found to be the most significant factor in determining risk of complication? | Operator experience |

## Landmark Research

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| What have studies evaluating surgical versus endovascular revascularization for RAS found? | One RCT showed no difference in outcomes including blood pressure, patency, and complications, but demonstrated a longer hospitalization postsurgical repair. A large meta-analysis showed better long-term patency and decreased blood pressure from surgical repair, but demonstrated higher surgical mortality, especially in poor surgical candidates. |
| What about comparing stenting versus angioplasty alone (in atherosclerotic patients)? | One small RCT, plus one meta-analysis, demonstrated that stenting had a significantly lower risk of restenosis, with no difference in blood pressure or renal outcomes, making stenting more favored when considering endovascular intervention in these patients. |
| What were the findings of the STAR, ASTRAL, and CORAL trials comparing medical therapy alone versus medical therapy plus endovascular revascularization? | Multicenter randomized controlled trials which found no significant difference in progression or renal disease (STAR and ASTRAL) or cardiovascular events, blood pressure changes, and all-cause mortality (CORAL), between medical therapy alone and medal therapy with endovascular revascularization |

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| What are some significant limitations of these (STAR, ASTRAL, and CORAL) studies? | Poor selection criteria<br>STAR:<br>Patients were selected by inaccurate, non-angiographic imaging.<br>No pressure gradient measured (no measurement of hemodynamically significance of RAS).<br>Used 50% stenosis as threshold, not 70% as is more standard.<br>ASTRAL:<br>Patients were excluded based on subjective opinion of their physician.<br>40% of patients had < 70% stenosis (likely not hemodynamically significant).<br>No pressure gradients measured.<br>Intervened on patients with contraindications.<br>CORAL:<br>Patients without HTN enrolled (RAS may not have been clinically significant).<br>Average % stenosis in treated group was < 70%.<br>In most cases, these studies did not include high-risk patients (pulmonary edema, etc.).<br>Poor technical outcomes in some, including higher complication rates and lower technical success rates than reported elsewhere, possibly due to inexperience of operators. |
| What is an argument in favor of the findings of the CORAL trial, as opposed to the others? | Selection criteria and decisions to intervene or not reflected current practice patterns at the time |

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| What is an important finding possibly supporting revascularization in all of the above, and other similar, studies? | Patient who underwent endovascular revascularization had a decrease in the number of antihypertensives needed to control their blood pressure, and the procedure is usually associated with a low complication rate in the hands of experienced operators. |
| What were the findings of studies that have included high-risk patients (including flash or recurrent pulmonary edema, multiple high-risk comorbidities, and progressive renal failure), and what are their limitations? | Endovascular revascularization was associated with reduced risk of death/survival advantage over medical therapy alone. However, these studies have mostly been small, non-randomized, single-center studies. |
| What is the current state of endovascular revascularization in cases of renovascular hypertension from atherosclerotic RAS based on these studies, as summarized in multiple meta-analyses, review articles, and ACR-SIR practice parameter? | No strong evidence for endovascular revascularization over medical therapy alone in the majority of cases of renovascular hypertension.<br>In a minority of severe cases of RVH, most notably in patients with flash or recurrent pulmonary edema, endovascular revascularization may be indicated.<br>Operator experience level seems to be an important predictor of outcomes.<br>More rigorous studies are needed, especially in high-risk patients. |

## Common Questions

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| What is the clinical hallmark of renovascular hypertension or HTN caused by RAS? | Poorly controlled HTN on optimal medical therapy with three different classes of drugs |
| What are the main causes of RAS? | Atherosclerosis<br>FMD |
| What subtype of FMD is most associated with RVH? | Medial |
| What is the best screening and follow-up imaging modality for RAS? | Renal duplex ultrasound |
| What is the gold standard for diagnosis, and why? | DSA, ability to measure translesional gradients |
| What is hemodynamically significant RAS? | > 10% or 10 mmHg mean pressure gradient and<br>> 20 mmHg systolic pressure gradient |
| What is the optimal treatment for RVH due to RAS? | Medical therapy including an ACE and/or an ARB |
| If intervening, what is the major difference in treating atherosclerotic versus FMD lesions? | Atherosclerosis: Stenting (usually with balloon angioplasty or balloon-mounted stents)<br>FMD: Balloon angioplasty only |

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| What presentation of RVH due to atherosclerotic RAS is the only indication with a class I recommendation for endovascular revascularization? | RVH causing cardiac destabilization, including flash and/or recurrent pulmonary edema<br>Key: Classification of recommendations and level of evidence<br>Class I: Benefit ≫ risk. Procedure should be performed.<br>Class IIa: Benefit > risk. It is reasonable to perform the procedure.<br>Class IIb: Benefit ≥ risk. Procedure may be considered.<br>Class III: No benefit, or there is harm. Procedure is not helpful or may be harmful.<br>Level A: Data from multiple RCTs or meta-analyses.<br>Level B: Data from one RCT or from non-randomized studies.<br>Level C: Limited data, only case studies or expert opinion. |

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# Chapter 27
# Varicose Vein

**Anushi Patel**

## Evaluating Patient

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| What should be evaluated on physical exam? | Physical exam should include inspection and palpation of both legs for asymmetry, edema, varicose veins, pigment changes, or ulcerations. These features help classify the severity of venous insufficiency. |
| What should be ruled out on physical exam? | Pedal pulses should be evaluated to exclude peripheral arterial disease as the etiology of the patient's clinical presentation and symptoms. Any signs of cellulitis or other infection are contraindications to treatment. |

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| What are different physical exam tests that can be done to evaluate for venous reflux? | Physical exam maneuvers to evaluate for venous reflux include the tap test, Perthes test, cough test, and Trendelenburg test. However, the use of duplex ultrasound has largely replaced the need of these maneuvers, which are now rarely performed. |
| How is venous reflux measured? | Evaluation for venous insufficiency is often performed either with the patient standing and supporting their weight with the contralateral leg or lying in reverse Trendelenburg. These maneuvers distend the veins and allow for measurement of reflux, usually with duplex ultrasound. The most routinely evaluated areas for reflux are the great saphenous vein (GSV), small saphenous vein (SSV), intersaphenous vein (ISV), any major tributary veins, popliteal fossa, saphenofemoral junction (SFJ), and any areas of symptoms. |
| What is the most frequently used imaging modality? | Duplex ultrasonography is most frequently used, which combines B-mode grayscale images, color Doppler images, and Doppler spectral waveform analysis. Air plethysmography is another commonly used modality that measures changes in limb venous volume with different maneuvers. This gives information about reflux, calf muscle pump function, ambulatory calf venous pressure, and venous obstruction. |

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| What findings indicate reflux on ultrasound examination? | A linear ultrasound probe is most commonly used for evaluation of vascular structures. A normal venous waveform should be relatively uniform, unidirectional, and nonpulsatile with phasicity (variation in flow related to respiration). Provocative maneuvers are used during the exam, such as distal venous compression with release (usually performed with an inflatable cuff) or Valsalva maneuver. If reflux (reversal of blood flow) is present during these maneuvers, there will be a transient inversion of the waveform on the velocity scale, indicating blood flow in the opposite direction. The duration of reflux is recorded. Incompetent perforating veins can have bidirectional flow. |
| What is the definition of venous reflux? | The definition varies in the literature. When referring to superficial veins, the most commonly accepted definition for delayed flow is flow reversal lasting at least 0.5 seconds. Greater than 1 second of reflux is abnormal. Perforating veins are considered abnormal if the diameter is over 4 mm or if normal in diameter with evidence for reflux lasting at least 0.35–0.5 seconds. |
| What additional details should be evaluated during ultrasound examination? | 1. Deep vein thrombosis (DVT) must be excluded, as the superficial venous system likely provides an important alternate drainage pathway (see below)<br>2. Variant superficial venous anatomy (see below) including the level of the SFJ<br>3. Superficial thrombosis<br>4. Diameter of GSV, SSV, or other target vein, including ≤2 cm from the deep vein junctions (femoral or popliteal)<br>5. Localization of incompetent perforating veins |

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| What is the utility of computed tomography (CT) and magnetic resonance venography (MRV) in the evaluation of venous disease? | CT and MRV are rarely needed for the evaluation of superficial venous disease as duplex ultrasonography is an adequate diagnostic modality. These modalities are more appropriate for patients with venous disease from suspected underlying proximal (iliofemoral) obstruction or iliac vein compression (May-Thurner syndrome). MRV is helpful for evaluation of vascular malformations from congenital venous disease. |
| What are complications of superficial venous insufficiency? | Infection, alterations in skin pigmentation, eczema, superficial thrombophlebitis, venous ulcers, loss of subcutaneous tissue, changes in lower leg circumference, lipodermatosclerosis, external perforation causing bleeding, edema, and atrophie blanche |
| How can chronic venous insufficiency be categorized? | The *CEAP* (*C*linical objective signs, *E*tiology of insufficiency, *A*natomical distribution, *P*athophysiology) classification aids in categorizing disease (Table 27.1). The Venous Clinical Severity Score is an additional scale more geared toward classifying the severity of disease (Table 27.2). These tools can be used during the initial and follow-up patient evaluations. |

Table 27.1 CEAP classification of chronic venous disease

| Classification | Symptom |
|---|---|
| *Clinical* | |
| $C_0$ | No visible or palpable signs of venous disease |
| $C_1$ | Telangiectases or reticular veins |
| $C_2$ | Varicose veins |
| $C_3$ | Edema |
| $C_{4a}$ | Pigmentation or eczema |
| $C_{4b}$ | Lipodermatosclerosis or atrophie blanche |
| $C_5$ | Healed venous ulcer |
| $C_6$ | Active venous ulcer |
| S | Symptomatic, including ache, pain, tightness, skin irritation, heaviness, and muscle cramps, and other complaints attributable to venous dysfunction |
| A | Asymptomatic |
| *Etiologic* | |
| $E_c$ | Congenital |
| $E_p$ | Primary |
| $E_s$ | Secondary (postthrombotic) |
| $E_n$ | No venous cause identified |
| *Anatomic* | |
| $A_s$ | Superficial veins |
| $A_p$ | Perforator veins |
| $A_d$ | Deep veins |
| $A_n$ | No venous location identified |
| *Pathophysiologic* | |
| $P_r$ | Reflux |

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Table 27.1 (continued)

| Classification | Symptom |
|---|---|
| $P_o$ | Obstruction |
| $P_{r,o}$ | Reflux and obstruction |
| $P_n$ | No venous pathophysiology identifiable |
| *Level of investigation* | |
| Level I | Office visit, with history and clinical examination, which may include the use of a handheld Doppler scanner |
| Level II | Noninvasive vascular laboratory testing, which now routinely includes duplex color scanning, with some plethysmographic method added as desired |
| Level III | Invasive investigations or more complex imaging studies, including ascending and descending venography, venous pressure measurements, computed tomography, or magnetic resonance |
| Example | A patient has painful swelling of the leg, and varicose veins, lipodermatosclerosis, and active ulceration. Duplex scanning shows axial reflux of the great saphenous vein above and below the knee, incompetent calf perforator veins, and axial reflux in the femoral and popliteal veins. There are no signs of postthrombotic obstruction. Classification according to basic CEAP: $C_{6,S,}$ $E_p$,$A_{s,p,d}$, $P_r$. Classification according to advanced CEAP: $C_{2,3,4b,6,S}$, $E_p$,$A_{s,p,d}$, $P_{r2,3,18,13,14}$ (2004-05-17, L II) |

Table 27.2 Venous Clinical Severity Score

| Attribute | Absent = 0 | Mild = 1 | Moderate = 2 | Severe = 3 |
|---|---|---|---|---|
| Pain | None | Occasional, not restricting activity or requiring analgesics | Daily, moderate activity limitation, occasional analgesics | Daily, severe limiting activities or requiring regular use of analgesics |
| Varicose veins | None | Few, scattered branch varicose veins | Multiple: GSV varicose veins confined to the calf or thigh | Extensive: thigh and calf or GSV and SSV distribution |
| Venous edema | None | Evening ankle only | Afternoon edema, above the ankle | Morning edema above the ankle and requiring activity change, elevation |
| Skin pigmentation | None or focal, low intensity (tan) | Diffuse, but limited in area and old (brown) | Diffuse over most of gaiter distribution (lower 1/3) or recent pigmentation (purple) | Wider distribution (above lower 1/3), recent pigmentation |
| Inflammation | None | Mild cellulitis, limited to marginal area around ulcer | Moderate cellulitis, involves most of the gaiter area (lower 2/3) | Severe cellulitis (lower 1/3 and above) or significant venous eczema |

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Table 27.2 (continued)

| Attribute | Absent = 0 | Mild = 1 | Moderate = 2 | Severe = 3 |
|---|---|---|---|---|
| Induration | None | Focal, circum-malleolar (<5 cm) | Medial or lateral, less than lower 1/3 of the leg | Entire lower 1/3 of the leg or more |
| Active ulcers, n | 0 | 1 | 2 | >2 |
| Active ulcer, duration | None | <3 months | >3 months but <1 year | Not healed >1 year |
| Active ulcer, size | None | <2 cm diameter | 2–6 cm diameter | >6 cm diameter |
| Compressive therapy | Not used or not compliant | Intermittent use of stockings | Wears elastic stockings most days | Full compliance: stockings + elevation |

## High Yield History

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| What are symptoms of lower extremity superficial venous insufficiency? | Symptoms include pain, burning, itching, aching, fatigue, swelling, restless legs, cramps, and heaviness. Symptoms are often worse at the end of the day, especially after periods of prolonged standing. Lower extremity elevation can alleviate symptoms. |
| What pertinent history should be collected? | Pertinent history to collect includes pregnancy status, family history, allergies, prior or current DVT or pulmonary embolism, recent diagnosis of malignancy, prior treatments for venous disease, and presence of known right-to-left heart shunt such as a patent foramen ovale (PFO), which increases the risk of complications. |

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| What are risk factors for developing lower extremity varicose veins? | Family history of venous disease (genetic predisposition), female sex, obesity, older age, pregnancy, prolonged standing, occupations associated with orthostasis, high estrogen levels, presence of an arteriovenous shunt, lower extremity trauma, ligamentous laxity (e.g., flatfeet), and smoking |
| What are some lifestyle modifications that can improve the symptoms of superficial venous insufficiency? | Exercise, leg elevation, weight loss, and avoidance of prolonged standing |
| What are rare congenital syndromes that involve venous insufficiency? | Klippel-Trenaunay syndrome is characterized by deep vein hypoplasia with aberrant venous pathways such as sciatic veins or persistent embryonic veins. Parkes-Weber syndrome is characterized by extensive lower extremity varices and arteriovenous malformations. These patients should be evaluated with both duplex ultrasound and MRV. |

## Indications/Contraindications

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| What are the indications for nonconservative treatment? | Any symptoms or complications attributed to superficial venous insufficiency refractory to conservative measures. Treatment can also be offered for asymptomatic cosmetic concerns. |

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| What are absolute or relative contraindications for treatment of superficial venous insufficiency? | DVT, pregnancy, lactation, immobility, uncorrectable coagulopathy, arterial insufficiency, infection, May-Thurner syndrome, arteriovenous fistula, congenital venous malformation, superficial thrombosis, presence of implanted pacemaker or nerve stimulator (only applies to first-generation radiofrequency ablation devices due to potential for signal interference), extreme tortuosity of the target vein for catheter-based ablation, severe edema for phlebectomy, inability to comply with post-procedural instructions, and allergy to local anesthetic or sclerosing agent |
| Why is it contraindicated to intervene on superficial venous insufficiency when there is an obstruction of the deep venous system? | Varicosities in the setting of deep venous system obstruction are hemodynamically useful collaterals for venous return. When they are treated or removed, the patient can experience significant pain and swelling of the extremity, recurrence of superficial varicose veins, and increased risk of soft tissue changes such as ulcers. |

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| What should be considered prior to the use of compression therapy? | Evaluation for coexisting arterial insufficiency should be performed including lower extremity pulse exam and ankle-brachial index (ABI), as needed. In patients with arterial insufficiency, compression therapy can worsen their symptoms/disease by limiting blood inflow. Therefore, it is contraindicated in patients with severe arterial insufficiency. Modified low-compression or nonelastic compression therapy (e.g., Unna boot) can be considered in patients with moderate arterial insufficiency, if tolerable and closely monitored for developing signs of limb ischemia. Compression therapy must also be used with caution in patients with peripheral neuropathy (contraindicated if severe), as they are prone to iatrogenic compression wounds or worsening pain, and in patients with heart failure, since therapy can increase cardiac preload. |
| What are the indications for ambulatory phlebectomy? | This minimally invasive procedure is often performed as an adjunctive therapy on varicosities that are palpable and closer to the skin surface, after the GSV or other main feeding vein is treated with endovenous therapy. It can also be used as isolated therapy for local disease. It can be performed on many different types of veins ranging from truncal veins (other than GSV/SSV) to reticular veins and perforators. Depending on user preference, phlebectomy can be used as an alternative to sclerotherapy. A potential complication of sclerotherapy is hemosiderin skin staining when used on varicosities closer to the skin. |

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| What is the overall treatment approach? | Practice varies but conservative measures are commonly prescribed for at least 3 months. This is often required by many insurance payors before nonconservative therapies are approved. In some patients, if compliant, compressive therapy is sufficient and can be continued long term. However, if there are persistent complications or unsatisfactory relief of symptoms on follow-up evaluation(s), nonconservative interventions can be pursued with typically one leg treated at a time. Clinical practice guidelines are available from various sources such as the Society of Interventional Radiology (SIR) and Society for Vascular Surgery (SVS) that can help direct treatment planning. |
| When should adjunctive therapy be performed? | Depending on operator preference, adjunctive phlebectomy or sclerotherapy can be performed during the same procedural visit as truncal ablation which can potentially decrease the overall number of visits, provide faster relief of symptoms, and decrease risk of superficial phlebitis. Alternatively, adjunctive therapy can be performed a few weeks or months after truncal ablation. This allows assessment for interval improvement and avoids a potentially unneeded procedure, since, in many cases, truncal ablation may be sufficient alone. This also allows the remaining varicosities to shrink in size which makes later adjunctive procedures easier and more effective to perform, if needed. |

## Relevant Anatomy

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| What are the superficial veins of the lower extremities? | The venous system of the lower extremities is divided into the superficial and deep venous compartments. Superficial veins of the lower extremities are those located between the deep fascia (which covers the muscles) and the skin. The two main superficial veins are the GSV and SSV. The SSV is also referred to as the lesser saphenous vein (LSV). |
| What is the saphenofemoral junction (SFJ)? | This is an important anatomical landmark which denotes the junction between the great saphenous vein (superficial system) and the common femoral vein (deep venous system). Within this region, there is also a confluence of multiple superficial inguinal and thigh veins including the external pudendal, inferior epigastric, and external circumflex iliac veins, among others. |
| What are varicose veins? | Varicose vein (also known as a varicosity) is a general term referring to a permanently dilated and tortuous subcutaneous vein ≥3 mm in diameter in the upright position. |
| What are truncal, tributary, and perforating veins? | Truncal veins are the major superficial veins such as the GSV, SSV, and large primary tributary veins. Tributary veins are branches of the major superficial veins. Perforating veins connect the superficial and deep venous systems and pass through the deep fascia that separates the superficial and deep compartments. |
| What are telangiectasias and reticular veins? | Telangiectasias (also known as spider veins) and reticular veins are dilated intradermal and subdermal veins, respectively. Telangiectasias are less than 1 mm in size. Reticular veins are 1–3 mm in size. |

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| What are some important anatomical variations? | Anatomical variations to consider include tortuosity of the target vein, atresia, accessory veins, variable course and termination of the SSV, duplications, and changes related to prior interventions (e.g., neovascularization or recanalization). For example, 1% of the population is estimated to have a duplicated GSV. Variations in the tributary veins of the GSV are also important. For example, many patients have an accessory anterior saphenous vein, which may also demonstrate reflux and need treatment. These different types of variations should be considered in preprocedural planning and may change approach to treatment. |

## Relevant Materials

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| What are the overall treatment options for superficial venous disease? | Conservative (compression therapy and lifestyle modifications), external laser, endovenous (thermal and nonthermal) including catheter-based techniques and sclerotherapy, and open/surgical including phlebectomy |
| How does compression therapy work? | Although there are many types of compression therapies, stockings are the most routinely used. They exert the greatest compression distally at the ankle with the degree of compression gradually decreasing up the garment as the limb circumference increases. This graduated compression helps blood to move up toward the heart and decreases pooling. Throughout the treated lower extremity, compression reduces venous hypertension, by augmenting the calf muscle pump, and decreases the vein diameter, which increases blood flow velocity. Overall, there is improved venous return and lymphatic drainage. |

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| What is the recommended degree of pressure for compression stockings? | Practice varies but frequently used is 15–20 mmHg for mild varicosities and symptoms, 20–30 mmHg for moderate-to-severe varicosities and symptoms, and 30–40 mmHg and above for severe varicosities with chronic complications of long-standing venous insufficiency. Degree of compression can also be increased if there is lack of clinical improvement. |
| Why is compression therapy used following superficial venous interventions? | Compression therapy decreases recovery time and post-procedural bruising/hematoma formation, swelling, and pain. This also ensures collapse/occlusion of the treated vein to prevent recanalization after endovenous therapy. There are variations in clinical practice and in data regarding the appropriate length of time or type (e.g., waist high or above the knee) of compressive therapy that should be used. Treatment varies depending on operator preference, but one common practice is for patients to have compression 24/7 for at least 1 week. Patients are also encouraged to ambulate after the procedure to prevent deep venous thrombosis, which is why immobility is a relative contraindication. |

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| What are the different types of endovascular therapies? | Therapy includes thermal endovenous ablation, most commonly for large tributary and truncal veins, and sclerotherapy, often a subsequent adjunctive treatment for the remaining small- to medium-sized veins. Endovenous therapy can also be classified into thermal techniques and nonthermal techniques. Thermal ablation includes endovenous laser therapy (EVLT), radiofrequency ablation (RFA), and steam vein sclerosis. Nonthermal ablation includes chemical sclerotherapy, combined mechanochemical ablation (MOCA), and injection of cyanoacrylate glue. EVLT and RFA are catheter-based ablation techniques which have largely replaced traditional surgical ligation and stripping. |
| What are the open/surgical treatment options? | Traditional surgical ligation/stripping (includes the Linton procedure), cryostripping, ambulatory phlebectomy, powered phlebectomy, CHIVA technique, ASVAL technique, and subfascial endoscopic perforator surgery (SEPS) |
| What is tumescent anesthesia? | A liquid local tumescent anesthetic (often comprised of 0.1% lidocaine after dilution with saline) is administered around the target vein during thermal ablation or phlebectomy. This protects the perivenous tissue from the heat created during thermal ablation, partially compresses the vein to reduce the distance thermal energy must travel to the endothelium, dissects the vein free from surrounding tissues, and reduces pain during the procedure. The solution is usually buffered with sodium bicarbonate to reduce discomfort during initial injections of the anesthetic. |

## General Step by Step

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| What is external laser therapy? | This refers to non-endovascular laser therapy used externally along the skin surface. This therapy is usually used on telangiectasias and smaller reticular veins for cosmetic purposes. Different types of laser machines are available, which deliver different wavelengths of light that penetrate through the skin and into the blood vessels where it is absorbed by hemoglobin leading to thermocoagulation. |
| What is sclerotherapy? | This is also referred to as chemical endovenous ablation. This is performed either with ultrasound guidance or direct visualization if injecting smaller veins along the skin. The lumen of the target vein is injected with a sclerosing substance. The sclerosing substance displaces blood and reacts with the endothelium which collapses and scars the vein. Different types of sclerosing agents are available such as hyperosmotic solutions (e.g., hypertonic saline), detergents (e.g., sodium tetradecyl sulfate), and corrosive/alcohol solutions (e.g., glycerin). Only a few detergents are approved by the Food and Drug Administration (FDA). Although it can be used to treat larger truncal veins, sclerotherapy is most routinely used on small- to medium-sized veins such as tributary veins, smaller truncal veins, accessory veins, perforators, reticular veins, and telangiectasias. The concentration and volume of agent used should correlate with the size of the targeted vein. |

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| What is foam sclerotherapy? | This refers to a method in which the sclerosing agent is combined with air to form a foam consistency. This is usually performed with the Tessari method via a three-way stop cock with about a 4:1 air to sclerosant agent ratio. Compared to simple liquid sclerotherapy, this causes an expansile effect with increased displacement of blood and contact with the endothelium for a suggested greater sclerosing effectiveness. Foam sclerotherapy is usually performed under ultrasound guidance. |
| How is the patient positioned during GSV ablation? | The patient is placed supine or oblique on a table with external rotation of the extremity at the hip and slight flexion at the knee. When access is obtained, the patient is placed in the reverse Trendelenburg position to distend the veins. When ablation is performed, the patient is placed in the Trendelenburg position to decrease intravascular volume and facilitate contact of the catheter tip with the vein wall for optimal ablation results. |
| What is the target zone for thermal endovenous ablation of the GSV? | Most commonly, the target zone extends from about 2 cm distal to the SFJ (or just distal to the origin of the superficial epigastric vein) to around the level of the knee. If needed, an extended treatment of the below-knee segment of the GSV can also be performed (although less frequently performed due to risk of damage to the adjacent saphenous nerve) with a target zone extending down to the inferior most point of reflux that is accessible by the catheter length. |

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| How is thermal endovenous ablation of the saphenous vein performed? | Using ultrasound guidance, antegrade access is obtained at the distal aspect of the targeted vein with a micropuncture set which is exchanged for a vascular sheath. The ablation catheter is threaded distal to proximal along the target zone. This is because it is easier to pass a catheter in the same direction of valve opening. Tumescent anesthesia is administered with ultrasound guidance. The catheter tip emits energy (radiofrequency waves or laser), and the catheter is continuously withdrawn at a rate dependent on the targeted segment of vein and the device and settings used (e.g., 2 mm per second, with most targeting an energy density of 80–100 J). As the catheter is withdrawn endothelial damage and thrombosis of the vein occurs. |
| How does the mechanism of action differ between EVLT and RFA? | In RFA, the electrode directly contacts the vein endothelium releasing radiofrequency energy and causing resistive heat-induced venous spasm, thrombosis, and denaturation of the wall collagen network leading to fibrosis. Laser (EVLT) induces a photothermolytic process which releases thermal energy both to the blood, causing blood to coagulate and form steam bubbles, and to the venous wall, causing transmural vein wall damage including microperforations. This inflammatory process causes thrombosis and fibrosis of the vein. |

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| How is ambulatory phlebectomy performed? | Ambulatory phlebectomy, also known as stab phlebectomy, involves removal/avulsion of varicose veins. With the patient standing, the target vein(s) is(are) mapped and marked on the skin using visual skin changes or ultrasonography. With the patient supine, tumescent anesthesia is administered. With a small blade, a series of 1–2 mm stab incisions are made several centimeters apart in the soft tissues overlying the targeted vein. Avulsion of the vein is performed with hooks or forceps that pull the vein to the surface at each incision site. This releases the vein from the surrounding tissues and severs any connections. The targeted vein is then removed. Since the incisions are small, they are closed with Steri-Strips and dressings. |

## Complications

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| What are complications of external laser therapy, sclerotherapy, endovenous ablation, and/or ambulatory phlebectomy? | Most complications overlap among the different therapies and include skin pigmentation changes such as bruising or hemosiderin staining (usually temporary), temporary or permanent nerve injury/paresthesia (most commonly affecting the saphenous, sural, common peroneal, and cutaneous nerves), superficial thrombophlebitis, burns, deep venous thrombosis, pulmonary embolism, telangiectatic matting, hematoma/bleeding, pain, allergic reaction to the sclerosing agent or anesthetic, recanalization/recurrence of veins, infection, and tightness along the course of the treated vein. |

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| What are additional rare complications of sclerotherapy? | Complications include pulmonary embolism, headache, visual changes, transient ischemic attack or stroke, heart attack, loss of limb (arterial stick), and death. These can be attributed to unintended embolization of the sclerosing agent. There is a greater chance of some of these complications if the patient has a PFO. |
| What are complications more specific to ambulatory phlebectomy? | Skin changes at the incision sites (blisters, keloid formation, dimpling, induration), hematoma, seroma, lymphocele, thrombophlebitis of the remaining vein if incompletely removed, telangiectatic matting, and nerve damage |
| What are complications of compression therapy? | Complications include limb ischemia, contact dermatitis/allergic reaction, pain, and skin necrosis/wound. These complications can be prevented or treated with local wound care, adjustments in wrapping technique, reduction in compression strength, or termination of therapy. |

## Landmark Research

Brittenden J, Cotton SC, Elders A, Ramsay CR, Norrie J, Burr J, et al. A randomized trial comparing treatments for varicose veins. *N Engl J Med*. 2014;371(13):1218–27.

- Comparison of Laser, Surgery, and Foam Sclerotherapy (CLASS) trial
- 798 participants with varicose veins were randomized to foam sclerotherapy, endovenous laser ablation, or surgery.
- The primary outcomes included disease-specific quality of life measures and generic quality of life measures at

6 months. Secondary outcomes included complications and measures of clinical success.
- Quality of life measures were similar among the three study groups except for a slightly worse disease-specific quality of life measure in the foam treatment group but similar outcomes in the laser and surgery groups.
- The frequency of complete successful ablation of the great saphenous vein was similar in the surgery (84.4%) and laser treatment (83.0%) groups but lower in the foam treatment group (54.6%).
- The frequency of procedural complications was similar in the foam (6%) and surgery groups (7%) but lower in the laser group (1%).

Nesbitt C, Bedenis R, Bhattacharya V, Stansby G. Endovenous ablation (radiofrequency and laser) and foam sclerotherapy versus open surgery for great saphenous vein varices. *Cochrane Database Syst Rev*. 2014;(7):CD005624.

- 13 randomized controlled trials of 3081 patients were included to determine the efficacy of endovenous ablation (radiofrequency and laser) and ultrasound-guided foam sclerotherapy compared to open surgical saphenofemoral ligation and stripping of GSV varices.
- Primary outcomes included recurrent varicosities, recanalization, neovascularization, technical procedure failure, patient quality of life scores, and complications.
- Ultrasound-guided foam sclerotherapy and endovenous ablation (radiofrequency and laser) are at least as effective as surgery in the treatment of great saphenous varicose veins.

van der Velden SK, Biemans AA, De Maeseneer MG, Kockaert MA, Cuypers PW, Hollestein LM, et al. Five-year results of a randomized clinical trial of conventional surgery, endovenous laser ablation and ultrasound-guided foam sclerotherapy in patients with great saphenous varicose veins. *Br J Surg*. 2015;102(10):1184–94.

- 224 legs were randomized to conventional surgery (69), EVLT (78), and ultrasound-guided foam sclerotherapy (UGFS) (77).
- The rates of great saphenous vein obliteration/absence were 85%, 77%, and 23% in the conventional surgery, EVLT, and UGFS groups, respectively, at 5 years.
- EVLT and conventional surgery were more effective than UGFS in obliterating the great saphenous vein 5 years after intervention.

## Common Questions

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| What is the pathophysiology of venous insufficiency? | Incompetent valves allow blood to flow in the opposite direction (reflux). This leads to pooling of blood, weakened vein walls (in part due to changes in wall collagen/elastin composition), failure of the calf muscle pump, and dilated superficial veins due to high pressure in a normally low-pressure system (venous hypertension). Along with subsequent leakage of fluid into surrounding soft tissues, this overall process gives rise to the physical manifestations of venous insufficiency (see above). Etiology is either primary or may be secondary to an occlusion in the deep venous system with subsequent reflux via the deep-to-superficial venous junctions or perforating veins. The secondary etiology causes the superficial venous network to function as a collateral flow system. |
| What are some benefits of endovascular treatment over surgery? | Reduced number and size of incisions, performed outpatient with no need for hospital stay, quicker recovery and return to work, less post-procedural pain, and decreased procedural time |

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| As a part of post-procedural clinical follow-up, what specific tools can be used to assess outcomes after therapy other than history and physical exam? | Revised Venous Clinical Severity Score<br>Disease-specific quality of life (QOL) questionnaire<br>Duplex ultrasound (see below) |
| What should you see on follow-up ultrasound evaluation after successful endovenous therapy? | Short-term ultrasound evaluation should demonstrate an occluded vein (absent flow), thickened venous wall, and decreased vessel diameter. Long-term ultrasound evaluation may show absence of the treated vein or a small residual scarred down cord. Practice varies, but ultrasound follow-up is commonly performed at 3 days, between 1 and 6 months, and 1 year after the procedure. |
| Why are specific safety precautions taken during EVLT? | If laser therapy is used, state laws and regulatory agencies often require specific safety measures. These include the use of appropriate eye protection and postage of warning signs at entry ways during the procedure, among several other precautions. The wavelength of light emitted from the laser can otherwise damage the eyes and vision, especially the retina. |

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| How are complications of venous insufficiency treated? | Treatment of the underlying refluxing veins with the methods described above should be performed for more definitive results. However, there are many complications of venous insufficiency (see above) that require separate management other than compression therapy:<br>Acute bleeding from vein perforation will require leg elevation, a pressure hold to achieve hemostasis, and a hemostatic suture, if needed.<br>Superficial thrombophlebitis is most frequently treated with supportive care, such as warm compress application, oral NSAIDs, and topical therapies. If affecting a longer segment of the vein (at least 5 cm) or if located less than 3 cm from the SFJ, short-term anticoagulation can be considered.<br>Soft tissue infections, such as cellulitis, require antibiotic therapy.<br>Patients with venous ulcers or other chronic soft tissue changes related to venous insufficiency will need regular wound care follow-up for advanced wound dressings and compression therapy with specialized wraps/bandages such as an Unna boot. Venous ulcers are most frequently located along the medial malleolus. Oral medications (e.g., phlebotonics or pentoxifylline) can be considered. Ulcers may need surgical debridement or skin grafting. Ulcers are prone to superimposed infections which can even lead to osteomyelitis of the underlying bone, requiring long-term antibiotic therapy. |

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# Chapter 28
# Varicocele Embolization

**Avinash Pillutla**

## Evaluating Patient

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| What are the common physical exam findings in varicoceles? | Varicoceles may be asymptomatic, but commonly present with dull, aching, usually left-sided scrotal pain. Pain is typically worsened with standing and relieved by laying supine. Testicular atrophy may be present, believed to be from loss of germ cell mass by increased scrotal temperature. |
| What is the differential diagnosis in scrotal swelling? | Common causes of scrotal swelling include inguinal hernia, hydrocele, hematocele, and pyocele. Other considerations include heart failure, idiopathic lymphedema, liver failure, and lymphatic or venous obstruction. Epidermoid cysts of the scrotal wall have also been described. Neoplastic causes must be excluded. |

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| How are varicoceles diagnosed with the aid of sonography? | The sensitivity and specificity of varicocele detection is close to 100% with color Doppler ultrasound (US). US should be performed with the patient in both a supine and a standing position. The general appearance of a varicocele consists of multiple, hypoechoic, serpiginous, tubular structures of varying sizes larger than 2 mm in diameter. Large varicoceles can extend inferiorly to the testis. Color flow and duplex Doppler US demonstrates a venous flow pattern of phasic variation and retrograde filling during Valsalva maneuvering. |
| What are the grading criteria for varicoceles? | Grade 1 denotes small-sized varicoceles that are palpable only with Valsalva maneuver.<br>Grade 2 denotes moderate-sized varicoceles that are nonvisible on inspection but palpable upon standing.<br>Grade 3 denotes large-sized varicoceles that are visible on gross inspection. |
| Why are the findings of non-compressibility and right-sided presentation generally more concerning features of varicoceles? | Unilateral right varicoceles are rare and should therefore may represent more ominous pathologies that may cause inferior vena cava (IVC) obstruction since the right internal spermatic vein (ISV) directly drains into the IVC. Examples include renal cell carcinoma with IVC thrombus or right renal vein thrombosis with extension to the IVC. All unilateral right-sided varicoceles should be further investigated with a computed tomography (CT) of the abdomen and pelvis with contrast. Varicoceles on either side that do not decompress in the recumbent position (non-diminishing) also raise concern for obstruction such as thrombus or extrinsic masses and should be further evaluated by CT. |

## High Yield History

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| How common are varicoceles in the postpubertal population? | Varicoceles are a common finding and present in approximately 15–20% of postpubertal males. In addition, up to 40% of varicoceles are associated with male infertility. |
| What is the most common age of presentation for idiopathic varicoceles? | Idiopathic varicoceles most commonly present between the ages of 15 and 25. |
| Is there an inheritance factor in the development of varicoceles? | While genetic mechanisms predisposing to varicocele formation have not yet been discovered, there may be a genetic basis for valvular dysfunction leading to varicocele development as suggested by epidemiological studies. |
| How are varicoceles implicated in the development of infertility? | It is well established that varicoceles are strongly associated with male infertility. Up to 40% of males presenting varicoceles may suffer from infertility. Varicoceles can result in disordered spermatogenesis, germ cell sloughing within the seminiferous tubules, testicular atrophy, and decreased testosterone secretion. |
| Why is routine scrotal ultrasound important in evaluating men with infertility? | Varicoceles are present in 35–40% of infertile men and represent a highly treatable form of male infertility. Additionally, there is an association between testicular malignancies and male infertility; thus, scrotal ultrasound provides valuable information in the diagnostic evaluation of infertile men. Compared to clinical palpation, US evaluation provides added diagnostic information. |

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| What are the treatment options for varicoceles? Is there a benefit in treating varicoceles associated with infertility? | While symptomatic varicoceles warrant treatment by themselves, there is evidence supporting improvement in male infertility rates following varicocele treatment. Options include surgical varicocelectomy, which can be performed via open, laparoscopic, and robotic approaches. Newer microsurgical techniques also have been described. Percutaneous varicocele embolization has also emerged as a viable, minimally invasive option with comparable efficacy; however, no direct comparison between surgical and radiological approaches has been performed. |

## Indications/Contraindications

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| What are the indications for percutaneous endovascular treatment of varicoceles? | Indications for endovascular treatment of varicoceles include chronic pain, infertility, recurrent varicocele after surgical repair, and testicular atrophy with or without evidence of worsening semen parameters. |
| What are the contraindications for percutaneous endovascular treatment of varicoceles? | For varicocele embolization, no absolute contraindications exist outside of contrast allergy and severe coagulopathy. |
| What are the indications for surgical treatment of varicoceles? | Symptomatic varicoceles, hypogonadism, and infertility are all indications for surgical intervention. Criteria for varicocele-associated infertility include palpable varicocele with no evidence of female infertility or abnormal semen analysis. |

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| What are the contraindications for surgical treatment of varicoceles? | Relative contraindications for surgical varicocelectomy for infertility include severe oligozoospermia or azoospermia, high serum FSH concentrations, and small testes. Varicoceles that are clinically less severe than grade 1 can also be considered relative contraindications. |
| How do surgical and endovascular treatment of varicoceles compare in efficacy? | Standard laparoscopic and robotic surgical approaches have shown a considerable recurrence rate due to venous collaterals bypassing the inguinal portion of the spermatic cord, scrotal collaterals, and dilated cremasteric veins. Newer microsurgical techniques perform better in ligating collateral flow and have demonstrated low recurrence rates. Varicocele embolization allows for effective targeting of collateral flow of the ISV in addition to treating the ISV prior to branching within the inguinal canal. |

## Relevant Anatomy

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| What is the definition of a varicocele? | A varicocele is defined as the dilatation or tortuosity of the veins of the pampiniform plexus, which is a collection of collaterals and tributaries joining spermatic vein branches within the scrotum. |
| What are the anatomic differences between the left and right internal spermatic veins? | The left ISV drains perpendicularly into the left renal vein, whereas the right ISV vein drains obliquely into the vena cava. The course of the left ISV is also approximately 8–10 cm longer than the right. |

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| On what side do varicoceles generally occur? Why? | Varicoceles are more common on the left side (85%) due to (a) longer course of the left ISV; (b) perpendicular angle of insertion of the left ISV into the left renal vein; (c) occasional arching of the left testicular artery over the left renal vein causing external compression and left ISV reflux; and (d) compression of the left ISV by a distended descending left colon. |
| What are all of the structures within the spermatic cord? | The following structures are located in the spermatic cord: the testicular artery, the artery to the ductus deferens, the cremasteric artery, the cremasteric nerve, the testicular nerves, the vas deferens (ductus deferens), the pampiniform plexus, the tunica vaginalis, and lymphatic vessels. |
| What is the anatomic level at which the internal spermatic vein begins to demonstrate extensive branching? | The ISV begins to branch extensively at the level of the inguinal canal. |
| What are the possible collateral pathways to the internal spermatic vein when treating varicoceles? | Commonly developed collateral pathways to the ISV include parallel, colic, hilar, and capsular collaterals. |
| What are the various surgical approaches to varicocelectomy? | There are multiple approaches to varicocelectomy: retroperitoneal ISV ligation, laparoscopic ISV ligation, and inguinal or subinguinal approach varicocelectomies with or without microsurgery. |

## Relevant Materials

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| What are the most common embolic agents used in varicocele embolization? | The most common agents are metallic coils and liquid sclerosants, such as sodium tetradecyl sulfate (STS) and glue. These agents can be used independently or in combination. Glue embolization requires considerable operator experience. Sodium tetradecyl sulfate (STS) is a common liquid sclerosant. Metallic coils typically are 0.035–0.038 inches in diameter and can be delivered in the ISV with care not to encroach into the renal vein. |
| What agents can be used for post-procedure pain control? | Typically, a course of nonsteroidal anti-inflammatory drugs (NSAIDs) with or without additional nonnarcotic analgesics can be used. Narcotics are usually not used or necessary. |
| What standard features of fluoroscopic equipment can be used to minimize testicular radiation exposure? | Use of the last image hold as opposed to spot film acquisition and avoidance of formal DSA "runs." |

## General Step by Step

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| What is the relevant laboratory workup prior to varicocele embolization? | Pre-procedural laboratory workup is not routinely performed in otherwise healthy, young males. |

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| What is the technique for successful retrograde advancement of a selective catheter in the ISV? | Successful advancement can be facilitated by coaxial insertion of a 4–5 Fr angled catheter with gentle injection of contrast to opacify the ISV in a retrograde fashion through incompetent valves. Valsalva maneuvering will aid in opacification of the ISV by increasing abdominal pressure. Tilting the table in a reverse-Trendelenburg position may be of benefit if Valsalva cannot be adequately performed. |
| What is a common technique of embolization? | Coil embolization of the entire ISV with or without liquid sclerosant for the pampiniform |
| After embolization of the ISV and collateral flow, what findings on venography signify procedural success? | Venography performed with Valsalva maneuvering demonstrates no reflux of flow down the gonadal vein. |
| After varicocele embolization and stasis of flow in the gonadal vein and pampiniform plexus, what additional step is required to prevent procedure failure? | Repeat venography must be performed to identify and embolize any new significant collateral pathways developing because of flow redistribution from embolization. |

## Complications

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| What are the potential complications of surgical techniques in treatment of varicoceles? | Surgical complications include testicular arterial injury, postoperative hydrocele, testicular atrophy, infection, and recurrence of varicoceles. A newer surgical technique called microsurgical varicocelectomy has a higher success rate and lower complication rates when compared with older laparoscopic and robotic techniques. The risk of general anesthesia for surgical approaches should also be considered. |
| What are the potential complications of endovascular techniques in treatment of varicoceles? | Varicocele embolization can result in coil misplacement or migration, venospasm or venous perforation, phlebitis, and testicular radiation exposure. |
| What steps can be taken to minimize the risk of metallic coil migration after varicocele embolization? | Though rare with modern coils, inappropriately sized metallic coils can become dislodged and migrate centrally to the pulmonary circuit. Care must be taken to appropriately size coils (approximately 120% of the ISV diameter), and to avoid protrusion of the cephalad-most coil into the left renal vein. |
| What procedure-related symptoms can be expected and are not necessarily considered complications? How can they be managed? | Commonly, patients may experience temporary back pain, mild scrotal swelling, and scrotal discomfort. These symptoms are generally self-limited, but can be treated with NSAIDs, heating pad, and rest for 2–3 days. |

## Landmark Research

Nork JJ, Berger JH, Crain DS, Christman MS. Youth varicocele and varicocele treatment: a meta-analysis of semen outcomes. *Fertil Steril*. 2014;102(2):381–387.e6. https://doi.org/10.1016/j.fertnstert.2014.04.049

- Meta-analysis of changes in semen as measured by semen analysis (SA) in youth with varicocele or undergoing varicocele treatment.
- Measured the effect of varicocele on semen and the effect of varicocele treatment on semen as measured by SA.
- Sperm density, motility, and morphology were significantly decreased when associated with a varicocele, and sperm density and motility were significantly improved following treatment of varicocele.

Kroese ACJ, de Lange NM, Collins J, Evers JLH. Surgery or embolization for varicoceles in subfertile men. *Cochrane Database Syst Rev*. 2012;10:CD000479. https://doi.org/10.1002/14651858.CD000479.pub5

- Meta-analysis to evaluate the effect of varicocele treatment on live birth and pregnancy rate in subfertile couples with known male varicocele.
- Ten randomized controlled trials included which reported pregnancy rates or live birth rates, and data in treated (surgical ligation or radiological embolization of the ISV) versus untreated or placebo groups.
- 894 men included from all studies. Study suggests low-quality evidence favoring benefit of varicocele treatment over expectant management for pregnancy rate in subfertile couples in whom varicocele was the only abnormal finding.

Marmar JL, Agarwal A, Prabakaran S, et al. Reassessing the value of varicocelectomy as a treatment for male subfertility with a new meta-analysis. *Fertil Steril*. 2007;88(3):639–648. https://doi.org/10.1016/j.fertnstert.2006.12.008

- Meta-analysis of two randomized controlled trials and three observational studies to assess the efficacy of varicocelectomy in treating male infertility by improving the chance of spontaneous pregnancy.
- Included infertile men with abnormal semen analysis and palpable varicocele who underwent surgical varicocelectomy; measured endpoint was spontaneous pregnancy.
- Odds of spontaneous pregnancy after surgical varicocelectomy were 2.87 (95% confidence interval [CI], 1.33–6.20), and the number needed to treat was 5.7 (95% CI, 4.4–9.5).

## Common Questions

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| What is the technical success rate of varicocele embolization? | There is a 93–100% technical success rate of varicocele embolization for untreated and recurrent varicoceles. |
| What is the potential result of too proximal of an embolization? | Too proximal of an embolization can lead to recurrence due to collateral pathways that can refill the varicocele through an inferior segment of the gonadal vein. |
| Does varicocele embolization require inpatient hospitalization? What is the expected time to recovery? | Varicocele embolization can be performed in the outpatient setting, requiring 2-hour monitoring prior to discharge. Typically, patients can return to work by the next day. |
| What is the clinical follow-up of patients after undergoing varicocele embolization? | Patients undergo a 3-month scrotal ultrasound to evaluate for adequate treatment response. |
| Which embolic agents are most associated with phlebitis? What is the treatment? | Glue and sclerosant embolics, especially if delivered below the level of the inguinal ligament, can be associated with phlebitis. While self-limited, NSAIDs and reduced physical activity can be recommended for symptom management. |

## Further Reading

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# Chapter 29
# Vena Cava Filter

**David Maldow**

## Evaluating the Patient

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| What are the physical signs and symptoms of lower extremity DVT? | Leg pain, pitting edema, rubor, and warmth |
| What is the initial imaging study of choice for evaluation of extremity DVT? | Duplex venous ultrasound |
| What are the key findings suggestive of venous thrombus on duplex ultrasound? | Absent compressibility. |
| | Loss of phasicity with Valsalva. |
| | Absent color flow (if occlusive). |
| | Lack of augmentation response. |
| | Change in venous diameter (generally increased if acute and decreased if chronic). |

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| | Proximal (iliofemoral) DVT – consider CT/MR venography as ultrasound exam is limited. |
| In pregnant patients, why should one consider suprarenal location for IVC filter placement? | To reduce radiation exposure to the fetus and to prevent complications between the fetus and filter |
| What is the optimal contrast bolus timing for visualization of the entire IVC on *CT*? | Approximately 90-second delay |

## High Yield History

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| What is Virchow's triad as it relates to the development of DVT? | Stasis, endothelial injury, and hypercoagulability |
| Name two transient risk factors for VTE. | Surgery and severe trauma (multiple long bone/pelvic fractures, spinal cord injury, and closed head injury) |
| Name two long-standing risk factors for VTE. | Malignancy and inherited coagulopathy (e.g., factor V Leiden deficiency) |
| Which allergy should be included in the history when evaluating a patient for vena cava filter placement? | Iodinated contrast (patient may require premedication regimen prior to procedure) |
| In the setting of iodinated contrast allergy, name two alternative contrast agents that may be used. | CO2 and gadolinium chelates |

# Indications/Contraindications

What are the prophylactic and therapeutic indications for IVC filter placement?

| Therapeutic indications | Prophylactic indications |
|---|---|
| DVT/PE with contraindication to anticoagulation | High-risk patient undergoing surgical procedure |
| Recurrent DVT/PE despite anticoagulation | Severe trauma (multiple long bone/pelvic fractures, spinal cord injury, or closed head injury) |
| DVT/PE with hemorrhage-related complications | High-risk patient secondary to underlying medical condition (prolonged immobilization) |
| Inability to maintain therapeutic anticoagulation | |

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| What is the first-line management of venous thromboembolism (VTE)? | Systemic anticoagulation (AC) |
| What is the dosing of anticoagulation regimens? | Unfractionated heparin: 80 units per kg IV bolus, followed by maintenance infusion 18 units per kg per hour titrated to a goal aPTT of 60–80 seconds or with Xa assay |
| | Enoxaparin (Lovenox, low molecular weight heparin): 1 mg per kg subcutaneously every 12 hours or 1.5 mg per kg subcutaneously every 24 hours |
| | Warfarin (Coumadin, vitamin K antagonist): 5–10 mg PO once daily titrated to INR 2 or greater |

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| | Apixaban (Eliquis, direct factor Xa inhibitor): 10 mg PO twice daily for 7 days and then 5 mg twice daily |
| | Rivaroxaban (Xarelto, direct factor Xa inhibitor): 15 mg PO twice daily for 21 days and then 20 mg once daily |
| | Dabigatran (Pradaxa, direct thrombin inhibitor): 150 mg PO twice daily |
| | Note: minimum 3-month therapy duration recommended |
| What type of filter is compatible for patients with megacava (caval diameter >28 mm)? | Cook Bird's Nest: non-retrievable, can be used with vena cava diameter up to 40 mm |
| Name three absolute contraindications to systemic anticoagulation. | Active bleeding, acute stroke within the past 24 hours, uncontrolled systolic hypertension (> or equal to 230/120 mmHg) |
| | Recent surgery or epidural intervention (e.g., lumbar puncture or epidural anesthesia) within prior 4 hours or expected within the next 12 hours |
| Name five relative contraindications to systemic anticoagulation. | Acquired bleeding disorder (e.g., inherited coagulopathy, liver failure) |
| | Stroke within the last 24 hours |
| | Uncontrolled hypertension (e.g., systolic > 230 mm Hg, diastolic > 120 mm Hg) |
| | Prior bleeding complication with systemic AC |
| | Sepsis |

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| Name three indications for suprarenal IVC filter placement. | 1. Renal vein or gonadal vein thrombosis |
| | 2. IVC duplication |
| | 3. Low insertion of renal veins |
| Name four indications for IVC filter removal. | Low risk of clinically significant PE due to primary treatment. |
| | Patient will not return to high risk for PE status from interruption of primary treatment. |
| | Life expectancy of patient long enough to realize benefit from filter removal (at least 6 months). |
| | Filter can safely be retrieved with adequate venous access. |
| Name two contraindications to vena cava filter removal. | 1. Significant thrombus within the filter |
| | 2. Patient unable to achieve adequate anticoagulation or prophylaxis |

## Relevant Anatomy

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| What defines a proximal lower extremity DVT? | Venous thrombus involving the popliteal vein, femoral vein, iliac veins or IVC |
| What defines a distal lower extremity DVT? | Venous thrombus confined to the infrapopliteal veins |
| What is the most common location for IVC filter placement? | Infrarenal |

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| What is the upper limit of caval diameter for filter placement? | 28 mm (excluding Bird's Nest filter) |
| Name four things to evaluate for on prefilter placement cavogram. | IVC duplication anomalies. In this case, a filter should be placed in both IVCs or in the bilateral iliac veins. |
| | Interrupted or absent IVC. |
| | Presence or absence of IVC thrombus. |
| | Determination of IVC diameter. |
| | Location of renal vein inflow. In the event of circumaortic left renal vein, the IVC filter should be placed below the level of the lowest renal vein or two can be placed in the bilateral common iliac veins. |
| What is the most common route of venous drainage in a duplicated IVC? | Left renal vein |
| Which gonadal vein drains into the IVC? | Right |
| How many left renal veins are seen with the circumaortic left renal vein variant? | Two. The filter should be placed below the level of the lowest renal vein. |

## Relevant Materials

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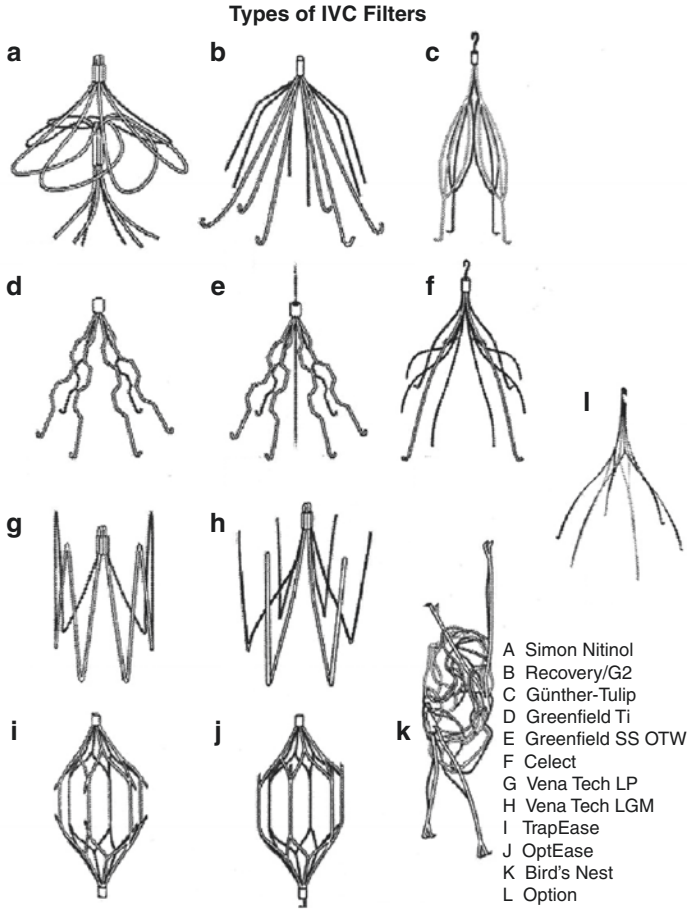
| What are the different types of historically available IVC filters? |

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| What are the names of two types of retrievable filters and what is their composition? | Cook Celect; conichrome<br><br>Cordis OptEase; nitinol |
| What are the names of two non-retrievable filter types and their composition? | Braun VenaTech LP or LGM; Phynox |

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| | Cook Bird's Nest; stainless steel |
| Name a contrast agent that can be used in a patient with renal insufficiency or iodinated contrast allergy. | CO2 |
| Name a common device used for vena cava filter retrieval. | Snare |

## General Step by Step

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| What are the two usual routes of peripheral venous access for IVC filter placement? | Internal jugular vein and femoral vein |
| What is the usual contrast injection rate for a cavogram? | 15–20 cc/sec for 2 seconds |
| How can you identify the contralateral iliac and renal veins on a cavogram? | Inflow of non-opacified blood or reflux of contrast into the veins |
| For the purpose of prefilter cavogram, where should the tip of the pigtail catheter be placed? | At the confluence of the iliac veins |
| At what level should the tip of the IVC filter be after deployment? | Generally, the tip is placed at the confluence of the renal veins as to allow renal inflow to help prevent thrombus formation. |

## Complications

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| Name three procedural complications of IVC filter placement. | 1. Incomplete filter deployment |

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| | 2. Filter malpositioning |
| | 3. Filter tilting |
| Name three late complications of IVC filter placement. | 1. Filter migration |
| | 2. Fractured filter limb |
| | 3. IVC thrombosis |
| What is a feared complication of infrarenal IVC filter placement in the setting of a duplicated IVC? | Recurrent pulmonary embolism. Filters should be placed in both IVCs or in the bilateral iliac veins. |

## Landmark Research

Haut et al. The effectiveness of prophylactic inferior vena cava filters in trauma patients: a systematic review and meta-analysis

- Weak association between IVC filter placement and decreased incidence of nonfatal and fatal PE in trauma patients. Benefits must be weighed against the inherent risks of IVC filter placement. Targeted use of IVC filters may be beneficial for those who are severely injured or unable to tolerate anticoagulation, particularly in the setting of retrievable filters.

Mismetti et al. Effect of a Retrievable Inferior Vena Cava Filter Plus Anticoagulation vs Anticoagulation Alone on Risk of Recurrent Pulmonary Embolism: A Randomized Clinical Trial.

- In patients with PE at high risk for recurrence, routine placement of a retrievable IVC filter does not reduce the risk of recurrent PE when compared to anticoagulation alone.

Decousus et al. A Clinical Trial of Vena Caval Filters in the Prevention of Pulmonary Embolism in Patients with Proximal Deep-Vein Thrombosis.

- No difference in 2-year mortality for DVT patients randomized to anticoagulation vs. filter.
- Although IVC filters reduced the risk of PE, they were associated with more recurrent DVT.

## Common Questions

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| True or false: vena cava filters help prevent formation of new thrombus. | False |
| What imaging study should be performed prior to removal of a prophylactic vena cava filter? | Doppler venous ultrasound of both lower extremities may be obtained as clinically indicated to document absence of DVT. |
| Should anticoagulation be held temporarily for vena cava filter removal? | No |

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# Chapter 30
# Peripheral and Visceral Artery Aneurysm

**Jesse Chen and Amit Ramjit**

## Evaluating Patient

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| What and where are PAAs? | Although aortic aneurysms are more common, PAA is an enlargement in an artery other than the aorta, the aorto-iliacs, the cerebral circulation, the visceral circulation, or the coronary vessels. They occur most commonly in the popliteal *arteries* (nearly 70% of all PAAs), followed by the iliofemoral arteries. Upper extremity PAAs are relatively uncommon. An aneurysm is a dilation of an artery >50% of its native diameter, and it involves *all three layers* of the arterial wall. |

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| How do PAAs present? | PAAs are usually asymptomatic and identified incidentally during workup for other reasons. Nonetheless, the most common acute presentation includes peripheral thrombosis with acute limb ischemia (pain, numbness, loss of pulses, etc.), representing roughly 50% of symptomatic PAAs. If there is insufficient flow past a thrombosed aneurysm, ensuing chronic limb ischemia can mimic occlusive atherosclerotic disease. Symptomatic aneurysms may also present secondary to compression of local structures (e.g., nerves, veins). PAAs are much less likely to rupture than aortic aneurysms, with an incidence of 2–4%. |
| What symptoms are typical of upper extremity PAAs? | The most common presenting symptoms result from subclavian artery aneurysms, including a pulsatile neck mass, upper extremity neuralgia, Horner syndrome, or stridor from tracheal or recurrent laryngeal nerve compression. |
| Are PAAs usually isolated findings? | No. identification of a single PAA warrants a thorough search for additional aneurysms. Roughly 83% of patients who have at least one PAA identified will be found to have multiple, including an increased risk for abdominal aortic aneurysm (AAA). For example, isolated popliteal artery aneurysms are very uncommon, found in only 0.1–3% of the population. Popliteal aneurysms are bilateral in 50–70% of cases, and up to 70% of patients with a popliteal aneurysm will have an AAA. |

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| How are PAAs evaluated and followed? | Because many aneurysms are asymptomatic for a prolonged period, the true incidence of PAAs is unclear. Ultrasonography has improved detection of peripheral aneurysms above physical exam, but computed tomography angiography (CTA) and magnetic resonance angiography (MRA) have since surpassed duplex ultrasound. Cross-sectional imaging provides better anatomical detail, allows definition of both inflow and outflow vessel diameter, and assesses for the presence of aneurysmal thrombus, all of which are important for intervention. |
| What will be found on physical exam of a PAA? | PAAs are usually diagnosed incidentally by imaging performed for other reasons. Due to differences in body habitus, physical exam generally has low sensitivity for PAA. Popliteal artery aneurysms, however, are classic for presenting with a pulsatile mass, found in 60% of patients. If a PAA is thrombosed, the only finding on physical exam to suggest its presence may be a pulsatile mass on the contralateral side. |
| What is the most common upper extremity PAA? | Subclavian artery aneurysm comprises 88% of upper extremity arterial aneurysms. |
| Where is the most common visceral artery aneurysm? | Visceral artery aneurysms (VAAs) are rare (estimated prevalence of 0.01–0.2%). Although about 1/5 present as clinical emergencies, an increasing number of incidental VAAs are diagnosed due to the increasing prevalence of cross-sectional imaging. The splenic artery is the most common site, then hepatic artery, celiac artery, and SMA. |

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| What is the most common site of pseudoaneurysm (PSA) formation? | The common femoral artery is the most common site of PSA, largely secondary to iatrogenic puncture for arterial catheterization. Femoral PSA occurs in 0.6–6% of femoral interventions. The wide prevalence of coronary interventions in the United States accounts for a significant portion of these PSAs, usually from a "low puncture" where the artery is not supported by surrounding structures (e.g., femoral head) to aid in hemostasis. Degenerative PSA formation over time is also common in arteriovenous fistulas created for hemodialysis. |
| How do pseudoaneurysms present? | Patients will present with symptoms of mass effect, bleeding, a palpable mass, or the sensation of pain or a femoral bruit. The expanding PSA may compress the adjacent nerve or vein, resulting in distal extremity numbness or edema, respectively. The overlying skin may develop ischemia, also from underlying compression. |
| How are pseudoaneurysms evaluated and followed? | Duplex ultrasonography has a sensitivity and specificity of 94% and 97%, respectively, for femoral PSA. Color Doppler will demonstrate a swirling pattern of flow, often referred to as the classic "yin-yang sign." to-and-fro flow signal in the PSA sac indicates a patent and non-thrombosed pseudoaneurysm with inflow and outflow. |

## High Yield History

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| What are the risk factors for PAA? | Male gender (M:F ratio >20:1), hypertension, family history of aneurysm, connective tissue disorder, smoking history, or prior aneurysm. In contrast, certain visceral artery aneurysms (e.g., splenic artery, renal artery) are more common in women. |
| What is the natural history of a PAA? | The most common complication of popliteal artery aneurysms (the most common PAA) is acute ischemia, either from thrombosis or distal embolization. Intermittent claudication, pain, and venous compression resulting in DVT are also potential complications. Femoral artery aneurysms (FAAs), the second most common PAA, do not have a well-defined natural history. Perhaps due to the relatively low incidence and often asymptomatic nature of FAA, multiple small case series demonstrate wide variability in the rate of complication. In general, PAA growth and the potential for rupture are difficult to predict. Some PAAs do not expand over time.<br>Upper extremity PAAs, however, more frequently become symptomatic than lower extremity PAAs, with thromboembolic complications being most common. Rupture is less likely the more distal the aneurysm in the upper extremity. |
| What is the natural history of visceral artery aneurysms (VAAs)? | The natural history of VAAs is unknown. Most symptomatic patients present following rupture with significant associated morbidity; however, no definite risk factors predisposing VAA to rupture have been identified. Because even small VAAs can rupture, no size criteria for repair are defined. Although splenic artery aneurysms are least likely to rupture, there is increased risk for rupture during pregnancy. Hepatic artery aneurysms have a relatively high risk of rupture. |

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| What is the association of splenic artery aneurysms and arterial calcification? | Calcification has been traditionally thought to represent aneurysmal stability; however, calcification is seen in 90% of ruptured splenic aneurysms, and thus the presence of calcifications should not be used in risk assessment. |
| What are the risk factors for PSA formation? | Poor puncture technique (as above), inadequate postprocedural puncture site compression, periprocedural anticoagulation, large-bore sheath placement (≥7 Fr), hypertension, coagulopathy, hemodialysis, and female gender |

## Indications/Contraindications

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| What is the indication for PAA repair? | All symptomatic PAAs should be repaired. Additionally, a PAA should be repaired when it is twice the size of the native vessel or when increasing in size. As a rule of thumb, most aneurysms ≥2 cm require treatment. Unfortunately, aneurysm diameter does not predict risk of rupture as compared to abdominal aortic aneurysm. |
| What patient factors preclude endovascular repair of popliteal artery aneurysm? | Patients who often maintain >90° flexion of the knees (e.g., gardeners, carpenters) have higher risk of stent kinking/occlusion. Additionally, stenting should not be performed in patients with contraindication to antiplatelet drugs. |
| In what clinical scenario is open surgical intervention recommended over endovascular repair for PAA? | In cases of aneurysm rupture and hemodynamic instability, or where the patient's anatomy is unsuitable for endovascular repair. There is currently no good data on endovascular management in the emergent setting. |

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| What is the indication for visceral artery aneurysm (VAA) repair? | Traditionally, intervention has been recommended for aneurysms ≥2 cm, aneurysms with rapid growth, or any symptomatic aneurysm. With increasing use of endovascular repair, and with poor data on size criteria as an indication for intervention, earlier and more aggressive intervention is replacing serial surveillance. Intervention should be offered to pregnant women with splenic artery aneurysm due to the increased risk of rupture. |
| What is the indication for PSA treatment? | The main consideration for treatment is whether the PSA will spontaneously thrombose, with likelihood generally tied to the size of the PSA. Limited studies have been inconsistent although, in general, a PSA <2 cm can be safely observed, a PSA ≥3 cm should be treated, and those measuring 2–3 cm should be more closely monitored or treated. Otherwise, all symptomatic PSAs should be treated. This would include PSAs with associated soft tissue necrosis, distal neuralgia or ischemia, pain, or rapid expansion, regardless of size. |
| What are the contraindications to ultrasound-guided thrombin injection of PSA? | A short, wide PSA neck is a contraindication to thrombin injection for risk of thrombin distal embolization leading to thrombosis. Additional contraindications include overlying tissue necrosis, presence of AV fistula, and the presence of limb ischemia. |

## Relevant Anatomy

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| What are the proximal arteries of the lower extremity? | The external iliac artery turns into the common femoral artery at the inguinal ligament. The common femoral artery terminates after giving rise to the profunda femoris, then becoming the superficial femoral artery. The superficial femoral artery turns into the popliteal artery at the adductor canal. |
| What are the distal arteries of the lower extremity? | The popliteal artery terminates as the anterior tibial artery and the tibioperoneal trunk. The tibioperoneal trunk then divides into the posterior tibial and peroneal arteries. |
| What are the arteries of the upper extremity? | The subclavian artery terminates at the first rib, then becoming the axillary artery. The axillary artery terminates after giving rise to the circumflex humeral arteries, then becoming the brachial artery. The brachial artery bifurcates just distal to the humeral trochlea giving rise to the radial and ulnar arteries. |
| What part of the popliteal artery is most commonly affected? | Middle third. The proximal third is the second most affected, and aneurysm of the distal third is the least common. Aneurysms of the distal third of the popliteal artery often extend into the tibioperoneal trunk and are much more prone to thrombosis and subsequent embolization. The popliteal artery may be of increased susceptibility to aneurysm formation due to a complex embryology, associated with three original segments as described above. |
| What are the two types of common femoral artery aneurysms (FAAs)? | Cutler and Darling in 1973 originally classified FAAs according to their relation to the femoral artery bifurcation. Type 1 FAAs are limited to the common femoral artery, and type 2 FAAs extend into the bifurcation, involving the origin of the profunda or the superficial femoral artery. |

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| What portion of the splenic artery is most commonly affected by VAA? | Distal third, followed by middle third |

## Relevant Materials

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| What size sheath is used during endovascular repair of PAA? | Depending on the intended stent-graft size, a 6- or 7-F sheath is usually used. |
| How are stent-grafts advanced into the PAA? | Stents are advanced over a 0.018″ or 0.035″ guidewire which has been passed beyond the aneurysm. |
| What is a commonly used stent-graft? | The Viabahn Endoprosthesis (Gore, Flagstaff, Arizona) is a commonly used self-expanding, covered stent-graft. It has improved flexibility compared to older generation devices. |
| Are multilayered stents useful in PAA repair? | No. Multilayered stents have been associated with increased risk of stent thrombosis, both in PAA and AAA repair. |
| What medications are given during and after stent placement in PAA repair? | Heparin is often administered, with antiplatelet therapy started post-repair. Antiplatelet (clopidogrel, aspirin) therapy has been shown to be a predictor of endovascular repair success. |
| What size needle is typically used for ultrasound-guided thrombin injection of a PSA? | A 22-gauge needle is usually sufficient; however, a 21-gauge needle may be necessary for deeper lesions. |

## General Step by Step

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| What is the gold standard of treatment for PAA management? | Open repair including aneurysm resection and placement of an interposition or bypass graft, usually with a great saphenous vein graft. Repair with a prosthetic (Dacron or PTFE) graft is also possible. While aneurysm excision without vascular reconstruction is possible, many of these patients will subsequently have arterial insufficiency symptoms. |
| What are the advantages of endovascular management techniques for PAA? | Endovascular techniques are increasingly popular, particularly for patients with multiple comorbidities who might not tolerate anesthesia and surgery. Open surgical repair can be associated with significant morbidity from major surgical dissection. Endovascular techniques often afford decreased blood loss, shorter procedure time, and decreased length of stay compared to open procedures. Nonetheless, cost savings afforded by endovascular management (e.g., decreased operative time and length of stay) may be offset by the increased cost of devices needed for endovascular repair. |
| Why are femoral artery aneurysms less favorable for endovascular repair? | The close proximity to the inguinal ligament results in focal compression/bending, increasing the risk of focal neointimal hyperplasia and possible stent fracture. Additionally, the proximity to the femoral bifurcation/profunda makes the possibility of fracture particularly dangerous. |

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| In a patient with multiple aneurysms, which are treated first? | In general, any abdominal aortic aneurysm is treated first, except in the case of acute limb ischemia. Concomitant ipsilateral PAAs in tandem can usually be repaired in the same operative setting (e.g., femoral and popliteal aneurysm). In contrast, a staged management algorithm is usually used for contralateral PAAs. |
| What is the endovascular treatment of PAA? | Many of the anatomical considerations of endovascular therapy are similar to the treatment of abdominal aortic aneurysm. Stent placement requires a 1.5–2.0-cm proximal and distal landing zone, according to manufacturer specification, to minimize stent migration and endoleak. Given that the distal vessel is often of smaller diameter than the proximal aspect, multiple devices of unequal diameters are often necessary. The distal/smaller stent is placed first, and the larger stents are placed inside the prior, building proximally. Stent-graft size is often chosen with a small amount (1 mm) of oversizing. Completion angiography, often with a crossed joint in flexion, is necessary to confirm aneurysm occlusion and to ensure stent flexibility. |

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| How are PSAs treated? | The mainstays of treatment include ultrasound-guided direct compression of the PSA, ultrasound-guided thrombin injection, and open surgical repair. Less common endovascular approaches include utilization of coils, glue, and occlusive stents:<br>*Ultrasound-guided compression*: Pressure is usually held for up to two cycles of 10–20 minutes, assessing for persistent flow within the PSA after each cycle. The patient should then keep the affected leg flat for 6 hours, and the PSA should be reassessed for flow 24–48 hours later. Success rates of 66–86% are reported, depending on PSA size, anticoagulation status, and body habitus.<br>*Ultrasound-guided thrombin injection*: The PSA is punctured under direct visualization with US guidance. 0.1–0.2-mL aliquots of 1000 U/mL of thrombin are injected until flow in the PSA stops. The patient should be placed on bed rest for 1 hour with neurovascular checks performed, and the PSA should be reassessed for flow in 24 hours. Success rates of 93–100% are reported.<br>*Surgical repair*: In general, surgical treatment is indicated when (1) urgent control of the PSA is needed (e.g., rupture, rapid expansion, compressive neuropathy, or limb ischemia), (2) if a soft tissue defect is present (e.g., suture line dehiscence, wound infection, soft tissue ischemia), or (3) if a secondary pathology requires surgical intervention (e.g., presence of arteriovenous fistula or if the patient is undergoing anesthesia for separate procedure). To repair the PSA, a direct cut down is made to achieve proximal and distal control of the arterial lesion. The PSA is then opened and the arteriotomy is directly repaired with sutures, or, if there is significant injury to the artery, a saphenous vein graft may be used for an interposition graft or patch angioplasty. |

## Complications

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| Why is upper extremity PAA more dangerous than lower extremity PAA? | PAA in the upper extremity should be repaired, even when asymptomatic, as there is a greater risk of thromboembolism. |
| What is the complication rate of PAAs treated conservatively? | 42–75% of asymptomatic patients with PAA that are treated conservatively will develop complications in 5 years, with risks varying based on aneurysm location. 14% of popliteal artery aneurysms become symptomatic per year. |
| What complications arise from endovascular repair of PAA? | Puncture site hematoma, stent occlusion, stent migration or fracture, and endoleak |
| What is the most common complication of ultrasound-guided thrombin injection of PSA? | Distal embolization is reported in up to 2% of patients. In the event of embolization (either in the femoral artery or distally), the patient should be placed on therapeutic heparin, with a low threshold for catheter-directed thrombolysis with tissue plasminogen activator (tPA). |
| How are infected PSAs treated? | Conservative treatments (discussed above) are not appropriate for infected PSAs. Appropriate antibiotic therapy, debridement of infected tissue, and arterial repair (often with interposition graft) are critical. |

## Landmark Research

Lovegrove RE, Javid M, Magee TR, et al. Endovascular and open approaches to non-thrombosed popliteal aneurysm repair: a meta-analysis. *Eur J Vasc Endovasc Surg*. 2008;36:96–100.

- Meta-analysis comparing open and endovascular repair of popliteal artery aneurysm demonstrating no difference in long-term patency. Endovascular repair was associated with decreased operative time and length of stay, however, with increased risk of thrombosis/reintervention at 30 days.

Open Versus Endovascular Repair of Popliteal Artery Aneurysm Trial. Available from: https://clinicaltrials.gov/ct2/show/NCT01817660. NLM identifier: NCT01817660.

- The Open Versus Endovascular Repair of Popliteal Artery Aneurysm (OVERPAR) trial was a highly anticipated, prospective, multicenter, randomized clinical trial which began in 2013 and was expected to be the largest study to date to guide treatment in patients with popliteal artery aneurysm. The study was unfortunately terminated in 2017 due to difficulty in recruiting patients.
- Nevertheless, since the beginning of this trial, multiple studies have compared the outcomes of open versus endovascular repair of popliteal artery aneurysm.

Endovascular versus open repair of asymptomatic popliteal artery aneurysm. *Cochrane Rev*. 2014.

- At the time of publication, only one randomized controlled trial compared endovascular stent-grafting with conventional open surgery for unilateral or bilateral repair of asymptomatic popliteal artery aneurysm ($n = 15$ in each group). Given no clear difference in patency rates after 1 and 4 years between the two groups, it was concluded that endovascular repair of popliteal artery aneurysm should be a viable alternative to open repair on a case-by-case basis.

Eslami MH, Rybin D, Doros G, Farber A. Open repair of asymptomatic popliteal artery aneurysm is associated with better outcomes than endovascular repair. *J Vasc Surg*. 2015;61(3):663–9.

- At the time of publication, this was the largest retrospective comparative analysis demonstrating increased

frequency of major adverse limb events at 1 year with endovascular repair compared to open repair.

Shahin Y, Barakat H, Shrivastava V. Endovascular versus open repair of asymptomatic popliteal artery aneurysms: a systematic review and meta-analysis. *J Vasc Interv Radiol*. 2016; 27:715–722.

- The authors concluded that although endovascular repair is associated with shorter length of hospital stay, the rate of 12-month primary patency was better with open repair. Additionally, there are superior perioperative outcomes (graft occlusion and reintervention rate) with open repair.

Leake AE, Segal MA, Chaer RA, et al. Meta-analysis of open and endovascular repair of popliteal artery aneurysms. *J Vasc Surg.* 2017; 65(1): 246–56.

- At the time of publication, this study represented the largest published analysis of popliteal artery aneurysms, demonstrating that endovascular repair afforded fewer wound complications and shorter length of stay, however, with the cost of an inferior primary patency at 3 years.

## Common Questions

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| What is the average dose of thrombin needed in ultrasound-guided thrombin injection of PSA? | An average of 300 u (0.3 ml) of thrombin will result in stasis within a PSA. |
| What is the appropriate duration of antiplatelet therapy? | There is currently no specified duration of antiplatelet therapy. Various studies have described postoperative antiplatelet therapy ranging from 3 weeks to lifelong treatment. |

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| What is the "double rupture" phenomenon regarding visceral arterial aneurysm (VAA)? | The initial sudden onset abdominal or chest pain associated with aneurysm rupture stabilizes secondary to temporary/local tamponade. 6–96 hours later, sudden onset cardiovascular collapse results due to internal hemorrhage. |
| What is the most common presentation of renal artery aneurysm? | Hypertension |
| Type II endoleak after popliteal artery aneurysm repair is secondary to backflow from what vessel? | Geniculate artery |
| What is Kommerell's diverticulum? | Aneurysmal origin of an aberrant left subclavian artery in the setting of a right-sided aortic arch |
| Which type of aneurysm is more likely to rupture: True or false aneurysm (PSA)? | False aneurysms, without all three layers of arterial wall, are more likely to rupture. |

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# Chapter 31
# Hemodialysis Access Interventions

**Rana Rabei**

## Evaluating Patient

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| What are the important factors to consider in vascular access selection? | Life goals and life expectancy, timing and length of HD therapy, comorbidities, and risk of access-related complications |
| What is the appropriate imaging modality for vascular access patency surveillance? | Duplex ultrasound |
| What are the clinical findings suggestive of vascular access failure? | Pulsatile flow, absent or weak thrill, low flows during dialysis, prolonged bleeding after needle removal, and increased venous pressures |
| What clinical finding suggests central venous stenosis? | Ipsilateral arm, chest wall, or facial edema |

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## High Yield History

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| What is the prevalence of ESRD? | Over 650,000 annually in the United States |
| What are the two major categories of HD vascular access? | Central venous catheters, referred to as "temporary" access, and arteriovenous access, referred to as "permanent" access |
| What is the preferred mode of access for HD? | Autologous AVF due to better patency rates and lower rates of infection, associated with lowest mortality rates and lowest rates of re-intervention compared to AVG and CVC |
| What is the significance of Fistula First Initiative? | A collaborative quality improvement initiative between with the Centers for Medicare and Medicaid Services (CMS) and the ESRD Network that began in 2003 to increase AVF use among hemodialysis patients |

## Indications/Contraindications

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| When is placement of non-tunneled catheters for HD indicated? | Temporary dialysis access for acute HD needs, not recommended for use longer than 1 week |
| What are indications for fistulogram? | Clinical signs of graft dysfunction, decreased intra-access blood flow during hemodialysis, and evaluation of non-maturing fistulas |
| When is angioplasty of dialysis graft or fistula indicated? | A stenosis causing greater than 50% reduction in luminal diameter and clinical indicator of graft failure |
| What are the procedures available to salvage a thrombosed fistula? | Surgical thrombectomy and endovascular catheter-directed or mechanical thrombectomy |

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| Why is stent use limited in treatment of AVF or AVG stenosis? | Relative high complication rates including stent migration, fracture, and infection |
| What are the relative contraindications for endovascular access site interventions? | Severe contrast allergy and coagulopathy |
| What is an absolute contraindication for venous access intervention? | Active infection |

## Relevant Anatomy

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| What are the common sites of AVF formation? | Wrist/forearm, radiocephalic; upper arm, brachiocephalic or brachiobasilic |
| What are the common sites for AVG formation? | Forearm, brachiocephalic (looped); upper arm, brachiobasilic or brachioaxillary |
| What is the first choice for AVF access? | Radiocephalic, due to relative lower rates of steal syndrome and preservation of future opportunities for more proximal fistulas |
| What is the most common site of stenosis in a radiocephalic dialysis fistula? | Juxta-anastomotic segment |
| What is the most common site of stenosis in a brachiocephalic dialysis fistula? | Cephalic arch stenosis |
| What is the most common site of stenosis in a brachiobasilic dialysis fistula? | Proximal swing segment |

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| What is the most common site of stenosis in a dialysis graft? | Venous anastomotic stenosis |

## Relevant Materials

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| What is the preferred method of intervention for graft stenosis? | Percutaneous transluminal angioplasty (PTA) |
| What are the preferred types of balloons for PTA of stenotic lesions? | High-pressure noncompliant balloons. Less commonly cutting balloons and drug-coated balloons (DCBs). High-pressure PTA and cutting balloons are popular in in-stent restenosis. Recent data supports use of DCBs in recurrent (< 90 days) stenoses or stenoses involving the swing segment or cephalic arch. |
| What is the recommended stent type in salvage AV access procedures? | Self-expanding covered stents |
| What are the two FDA-approved endovascular AVF devices on the market? | Ellipsys and WavelinQ EndoAVF which use thermal energy to fuse arterial and venous walls and create a percutaneous anastomosis |

## General Step by Step

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| What imaging modality is useful to determine optimal access site for fistulogram? | Ultrasound |

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| What is the most common access point for fistulogram? | Anterograde puncture toward the venous outflow, just beyond the arterial anastomosis |
| What areas should be evaluated by diagnostic fistulogram? | Entire access including arterial anastomosis, fistula or graft, outflow veins including vena cava, and right atrium |
| What angiography finding is suggestive of significant upstream obstruction? | Presence of significant venous collaterals |
| What is the utility of nitroglycerin in fistulography? | Treatment of arterial or venous spasms |
| What is the basic technique of PTA for stenotic lesions? | Angioplasty catheter is inserted over guidewire and positioned across the lesion. Balloon is then inflated until a waist is visualized and eliminated. The balloon size is chosen based on visual estimation of the diameter of the vessel. |
| What is a successful angioplasty procedure? | Increased luminal diameter, visualization and elimination of waist angiographically, improved physical exam, and resolution of clinical symptoms |
| What factors should be considered in stenting stenotic lesions that fail PTA? | The diameter, length and location of lesion, and availability of surgical options |
| What medication is typically given during declot procedure? | 5000 U of heparin and/or tissue plasminogen activator (tPA) |

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| What are examples of declot techniques? | Balloon maceration of clot, infusion of access with thrombolytic agents, catheter-directed thrombectomy and thrombolysis using devices such as Arrow-Trerotola percutaneous thrombolytic device (PTD) (Arrow International, a division of Teleflex, Durham, NC), AngioJet Peripheral Thrombectomy System (Boston Scientific, Natick, MA), and Trellis-8 peripheral infusion system (Covidien, Mansfield, MA) |
| What is a common technique for addressing arterial anastomotic stenosis/plug? | Advancing a Fogarty balloon (Edwards Lifesciences; Irvine, California) through the retrograde sheath across the arterial anastomosis. Inflating the balloon and pulling back across the arterial anastomosis into the access |

## Complications

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| What is the most common complication of CVC? | Infection |
| What is the management for CVC infection? | Obtain cultures, perform appropriate antibiotic therapy, and catheters should be removed and replaced at a different site. |
| What are possible complications of PTA treatment of failing fistula? | Angioplasty-induced rupture (2–3%), bleeding from access site, persistent stenosis, and embolism |
| What is steal syndrome? | Low blood flow or ischemia to the extremity occurring due to flow into the fistula |

## Landmark Research

Young, et al. The Dialysis Outcomes and Practice Patterns Study (DOPPS): An international hemodialysis study. Kidney International. 2000; 57(74):S-74–S-81.

- DOPPS is an international prospective observational study of hemodialysis patients which began in 7 countries including the United States and has since expanded to 12 countries. This study aims to identify practice patterns associated with the best outcomes over time.
- DOPPS demonstrated that dialysis patients have a higher mortality in the United States compared to Japan and Europe which has been attributed to differences in practice patterns, particularly the type of vascular access at initiation of dialysis and length of dialysis sessions.

Astor B C, Eustace J A, Powe N R, Klag M J, Fink N E, Coresh J, CHOICE Study Type of vascular access and survival among incident hemodialysis patients: the Choices for Healthy Outcomes in Caring for ESRD (CHOICE) Study. J Am Soc Nephrol. 2005;16 (5):1449–1455.

- CHOICE is a longitudinal observational cohort study of 1041 incident dialysis patients funded by AHRQ to measure several aspects of patients' experiences and outcomes related to modality of renal replacement therapy.
- Survival rates stratified by the type of access in use demonstrated annual mortality rates of 11.7% for AVF, 14.2% for AVG, and 16.1% for CVC. Adjusted relative hazards (RH) of death compared with AVF were 1.5 for CVC and 1.2 for AVG. These results strongly support existing clinical practice guidelines that the use of venous catheters should be minimized to reduce the complications and to improve patient survival.

Lok CE, Huber TS, Lee T, et al.; KDOQI Vascular Access Guideline Work Group. KDOQI clinical practice guideline for vascular access: 2019 update. Am J Kidney Dis. 2020;75 (4)(suppl 2):S1–S164.

- The latest evidence-based hemodialysis vascular access guidelines provided by the multidisciplinary workgroup of the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI).
- The 2019 update introduces the concept of *ESRD Life-Plan*, recommending a comprehensive evaluation of patient's needs and preferences and developing a contingency plan on how to deal with vascular access complications during the initial planning of the first access. The benefits of this patient-centered approach are preserving vessels for future AV access, avoiding unnecessary procedures, and limiting complications

Rajan DK, Ebner A, Desai SB, Rios JM, Cohn WE. Percutaneous creation of an arteriovenous fistula for hemodialysis access. *J Vasc Interv Radiol*. 2015;26 (4):484–490.

- Nonrandomized prospective study to evaluate safety and efficacy of percutaneous system for creating AVF in dialysis patients. The primary endpoints were successful creation of patent AVF, maturation over time, and adverse events.
- 32 of 33 patients had successful AVF creation, cumulative patency at 6 months was 96%, mean time to maturation was 58 days, and there was one series procedure-related adverse event.

Lok CE, Rajan DK, Clement J, et al.; NEAT Investigators. Endovascular proximal forearm arteriovenous fistula for hemodialysis access: results of the prospective, multicenter Novel Endovascular Access Trial (NEAT). *Am J Kidney Dis*. 2017; 70 (4): 486–497.

- Prospective, single-arm, multicenter study to evaluate safety, efficacy, patency, and adverse effects of endovascular AVF creation.
- 80 patients enrolled, 98% with successful AVF creation, 8% had a serious procedure-related adverse event, functional usability was 64% in participants who received

dialysis, 12-month primary patency was 69%, and cumulative patency was 84%.

Haskal ZJ, Trerotola S, Dolmatch B, Schuman E, Altman S, Mietling S, Berman S, McLennan G, Trimmer C, Ross J, Vesely T. Stent graft versus balloon angioplasty for failing dialysis-access grafts. N Engl J Med. 2010 Feb 11;362 (6):494–503.

- Prospective, single-arm, multicenter trial to evaluate safety and 6-month arteriovenous graft patency in patients with venous anastomotic stenosis following balloon angioplasty or stenting.
- Patients who underwent stenting had significantly greater rates of patency at the site of the anastomotic stenosis and overall patency of the access circuit at 6 months with equivalent rates of adverse events.

## Common Questions

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| What is a mature fistula? | Fistula that can be repetitively cannulated and provide adequate blood flow for dialysis |
| How long does it take for a fistula to mature? | 4–6 weeks |
| What does primary patency refer to? | Duration of access patency from the date of vascular access creation/insertion to thrombosis or any intervention to facilitate, maintain, or re-establish patency |
| What is the primary complication that leads to graft failure? | Stenosis with subsequent thrombosis |

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| What is the underlying cause of access stenosis? | Intimal hyperplasia as a result of injury of the endothelium by surgical or hemodynamic stress leading to reduction of lumen size |
| What is the fistula rule of 6 s? | AVFs typically mature by 6 weeks post creation, should have a diameter of 6 mm, be less than 6 mm below the skin surface, and have a flow rate greater than 600 ml/min. |
| What is the life expectancy of autologous fistula compared to graft? | 3–7 years compared to 1–2 years |

## Further Reading

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# Chapter 32
# Hybrid and Complex Aortic Aneurysm Endovascular Repair

**Omosalewa Adenikinju, Sofia C. D. Vianna, and Brandon P. Olivieri**

## Patient Evaluation

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| What preoperative imaging should be obtained for planning? | CT angiogram (CTA) of the chest and/or abdomen and pelvis for chest and abdominal aortic pathology.<br>CTA of the head and neck for aortic arch pathology. This aids in evaluating the integrity of the circle of Willis, observing vertebral dominance, as well as identifying anatomic variants, which dictate treatment approach. |
| What are the indications for complex aortic repair? | Dissection, acute aortic injury involving the arch (i.e., rupture), or symptomatic or rapid growth of the aneurysm, extending to involve branch vessels or the proximal seal zone. |

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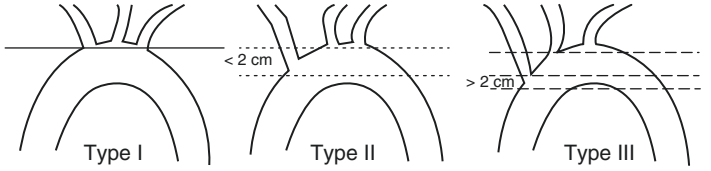
| What factors are important in stratifying patients to undergo hybrid thoracic aortic aneurysm repair over open repair? | Patient factors: age > 65, renal failure, CHF, and COPD<br>Surgical factors: unfavorable anatomy for open repair and unable to tolerate circulatory arrest |
| How is a complex hybrid aortic repair staged? | Staging is appropriate when thoracic and visceral or iliac artery treatments are both needed or when a bypass needs to be performed to maintain branch vessel perfusion (carotid-subclavian or external-internal artery bypass). |
| What are the advantages of thoracic aortic hybrid procedures? | 1. Eliminate or decrease time on extracorporeal membrane oxygenation (ECMO) and circulatory arrest<br>2. Decreased neurological complications<br>3. Possibility of avoiding sternotomy |
| What are the disadvantages of thoracic hybrid procedures? | 1. Risk of bypass thrombosis<br>2. Technically challenging overall, especially in patients with unfavorable anatomy, such as steep angulation which makes graft deployment difficult<br>3. Risk of interval aneurysmal rupture between staged operative interventions |
| What postoperative factor makes staged hybrid TEVAR ideal over single-session therapy? | Blood pressure management:<br>First stage (open repair): low MAPs preferred postoperatively in patients who have undergone open repair with cardiopulmonary bypass +/− hypothermia to prevent postoperative bleeding<br>Second stage (endovascular): high MAPs preferred to prevent cord ischemia |

# Relevant Anatomy

## *Complex Thoracic Aortic Aneurysm*

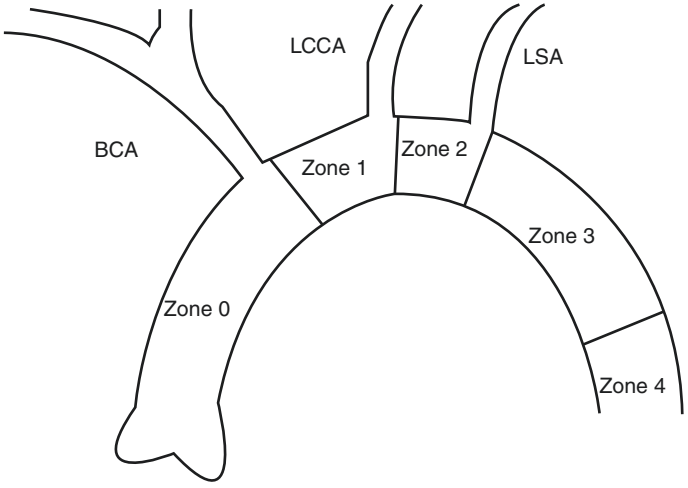
### Aortic Arch Variants

| Arch type | Branches (proximal to distal) |
|---|---|
| *Normal arch* | 1. Brachiocephalic trunk<br>2. Left common carotid artery<br>3. Left subclavian |
| *Bovine arch (10–20%)* | 1. Brachiocephalic trunk with left common carotid artery<br>2. Left subclavian artery |
| *Isolated vertebral (2.5–6%)* | 1. Brachiocephalic trunk<br>2. Left common carotid artery<br>3. Left vertebral artery<br>4. Left subclavian artery |
| *Aberrant right subclavian (0.6%)* | 1. Right common carotid artery<br>2. Left common carotid artery<br>3. Left subclavian artery<br>4. Right subclavian artery |




**Types of Aortic Arch**

- *Type I*: If the origins of all the great vessels arise within the arc segment of the aortic arch subtended by the first parallel reference line
- *Type II*: If the origins of all the great vessels are included in the arc segment of the aortic arch subtended by the second index line
- *Type III*: If the origins of all of the great vessels are included in the arc segment of the aortic arch subtended by the third index line

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| What are the landing zones for thoracic aortic interventions (Preventza, Xydas)? | Zone 0: Proximal to the right brachiocephalic artery<br>Zone 1: Between the right brachiocephalic and left common carotid arteries<br>Zone 2: Between the left common carotid and left subclavian arteries<br>Zone 3: Proximal descending aorta, distal to the LSA<br>Zone 4: Mid-descending aorta |
| Where is the aneurysm or pathology located in a zone 0 repair? | Transverse arch and/or proximal thoracic aorta |
| Where is the aneurysm or pathology located in a zone 1 repair? | Mid to distal arch +/− into the descending thoracic aorta |

## *Complex Abdominal Aortic Aneurysm*

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| What defines a complex AAA? | Neck length of < 15 mm, an aortic neck diameter of > 25 mm, and aortic neck angulation of ≥ 45° and < 10 mm of infrarenal aorta free of aneurysm<br>Involvement of at least one of its visceral branches such as renal, superior mesenteric, or celiac vessels<br>Crawford-type IV thoracoabdominal aortic aneurysm (TAAA) aneurysm that extends from the 12th intercostal space to the iliac bifurcation involving the visceral aortic segment and the origins of the renal, superior mesenteric, and celiac arteries (EVT type IV, etc.) |

| **Crawford classification (TAAA 1986)** | |
|---|---|
| Type I | Below the left subclavian artery to above renal arteries |
| Type II | Below the left subclavian artery to aortic bifurcation |
| Type III | 6th intercostal space to aortic bifurcation |
| Type IV | 12th intercostal space to aortic bifurcation |
| Type V | 6th intercostal space to above renal arteries |

# High Yield

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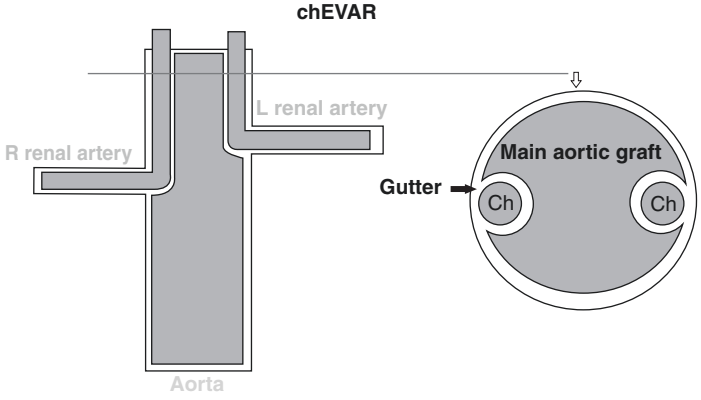
| What is the basic principle of complex thoracic hybrid repair? | Creating a way to maintain perfusion of the great vessels after ligation/embolization of their origin at the arch, followed by aortic stent graft delivery to treat underlying pathology |
| Most purely endovascular thoracic aortic repairs are performed for pathology most commonly in which zone? | Zone 4 (mid-descending aorta). Current investigations are underway examining technical success and safety of treating arch aneurysms and acute aortic injuries, including dissections in zones 0–2. |
| What are the types of EVAR options for complex aortic repair? | The exclusively endovascular repairs are divided into parallel and nonparallel grafts, based on the orientation of the branched stents in comparison with the main aortic grafts. |

| Endovascular | | Hybrid |
|---|---|---|
| **Parallel** | **Nonparallel** | **Debranching EVAR** |
| chEVAR (chimney aka snorkel) | Fenestrated | |
| Periscope or reverse chimney | Branched | |
| Sandwich[a] | EVAS (endovascular aneurysm sealing)[a] | |

Reference: Hybrid Repair of Suprarenal Abdominal Aortic Aneurysm: Antegrade Debranching with Endovascular Aneurysm Repair

[a]Denotes only in complex AAA repair

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| What is a chEVAR? | Chimney or snorkeling is also known as chEVAR and involves the placement of single or multiple stents in parallel to the main aortic graft. In order to maintain perfusion to the visceral vessels, these stents begin in the parent vessel adjacent to the edge or sealing zone of the main aortic graft and extend into branch vessels, which would normally be excluded by the main aortic graft. |

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| What is a periscope graft? | A "periscope" or "reverse chimney" technique describes the placement of the covered stent below the distal edge of the main aortic stent graft. This facilitates the extension of the distal seal zone in thoracoabdominal or abdominal aneurysms.<br>When used in TEVAR, it is used to preserve the LSA (Hakim). |
| What are the characteristics of a sandwich EVAR? | The "sandwich" technique involves the placement of a covered stent positioned between two aortic main body components in order to maintain side branch perfusion in mid-graft position. Novel approaches have been described utilizing a combination of chimney grafts and periscopes with and without sandwiching the grafts with a bridging graft in the treatment of thoracoabdominal aneurysms (TAAA). |
| Which are the advantages of using parallel endografts? | The parallel techniques are performed using a variety of endografts and covered or uncovered stents that are readily available "off-the-shelf" and employed on urgent cases. When compared to fenestrated and branched grafts (fEVAR) techniques, parallel techniques are usually cheaper and can be less time-consuming. Additionally, these techniques can be used as a "bail out" procedure in the setting of accidental over stenting of visceral aortic branches during conventional EVAR. |
| Which are the disadvantages of the parallel endografts? | The major disadvantage of EVAR via parallel techniques (chEVAR) is the development of gutter leaks, a form of type I endoleak caused by blood flow into the potential space between the aortic wall and the multiple stent grafts. Gutter leaks can also result in kinking, compression, and eventual occlusion of one or multiple graft components. Hakim et al. report resolution of most type 1a endoleaks after TEVAR on follow-up scans. |

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| How can risk of gutter formation be decreased? | Techniques that improve graft-aortic wall apposition decrease the rate of gutter formation. These include the use of more conformable aortic stent grafts, oversizing of the main aortic stent graft, and avoiding multiple chimney grafts. |
| What increases the risk of gutter formation? | Positioning the snorkeled or chimney grafts obliquely rather than parallel to the main aortic endograft decreases aortic wall apposition at the seal zone, resulting in increased chance for gutter formation. |
| What are fenestrated endografts? | Fenestrated grafts are composed of a main aortic endograft body that extends its proximal sealing zone above the infrarenal segment. These grafts have fenestrations or scallops corresponding to excluded visceral vessels in order to maintain the visceral perfusion.<br>Fenestrated endovascular aortic repair (fEVAR) maximizes the interaction between the aortic endograft and the aortic wall while maintaining visceral perfusion.<br>Planned overlap between aortic endograft and branch stents reduces the risk of component separation, type III endoleaks, and protrusion of branch stents into the main stent graft.<br>They are currently designed specifically for each patient using CT data, requiring time for construction. However, off-the-shelf varieties, which contain fenestrations and scallops to treat the majority of patient anatomies, are currently in development.<br>Fenestrated endografts can also potentially be created by the physician on the "back table" in a customized manner. |
| What are the advantages of fEVAR? | Fenestrated endografts have lower risk of proximal endoleaks in juxtarenal aortic aneurysms since they are free of gutters creating better sealing. They present better results in short- and long-term data when compared to chEVARs. The specific radiopaque markers offer guidance for optimal positioning. |

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| What are the disadvantages of fEVAR? | Most limitations are associated with the length of time needed to manufacture the customized fenestrated devices and higher cost. They are not available "off-the-shelf" thus they are not available in urgent settings. |
| What is a branched endograft? | Branched endografts are composed of a main body device with renal and visceral branches that extend to maintain flow. Manufacturers offer different devices with a wide variety of attachments for the branch components. The branched EVARs are currently Investigational Device Exemption (IDE) in the United States, though most of them are already approved in Canada and Europe. |
| What are the advantages of branched EVAR? | Branched devices also known as directional branched devices are used mainly for treatment of TAAAs. They present as an "off-the-shelf" option to long-segment TAAAs (Crawford IV), and are suitable for emergent or urgent cases. |
| Which are the disadvantages of the branched EVARs? | The coverage of long-segment TAAAs with endografts is associated with higher rates of spinal ischemia and its complications. |
| What is an EVAS? | The endovascular aneurysm sealing system (Nellix EVAS; Endologix, Irvine, CA, USA) consists of two balloon-expandable stents which support the aorta flow channel which expands from the non-aneurysmal aorta proximally to the iliac arteries distally. Surrounding the endografts, nonporous PTFE-based endobags are filled using biocompatible polyethylene glycol polymer, adjusting the endobag to fit the aneurysm sac lumen. This allows sealing of the aneurysm and resists displacement. At the time of authorship, the Nellix System is an investigational device as part of the EVAS2 study, in the United States. |

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| How much do the stent grafts need to be oversized? | Thoracic endograft stent is oversized 0–20% based on the pathology (i.e., aneurysm, dissection, trauma)<br>Chimney stent graft sizing is based on the type of graft:<br>Self-expanding stent graft: oversized 0–20% relative to the diameter of the branch vessel (e.g., Gore Viabahn (W.L. Gore & Associates, Flagstaff, AZ))<br>Balloon-expandable stent graft: oversized 0–5% (e.g., Atrium iCast) |
| Which type of chimney stent grafts is preferred? | Balloon-expandable stent grafts have higher radial force when compared to self-expanding stents, and thus have lower rates of reported occlusion. However, it must be kept in mind that the type of stent used is highly operator dependent, in the context of chEVAR, since it is considered an off-label procedure. |
| What is a Dacron elephant trunk graft (ETG)? | Ascending aortic hemiarch graft with proximal branch trifurcation anastomosis to the great vessels (simulating takeoff from a conventional three-vessel arch)<br>Frozen elephant trunk procedure is a surgical option, which allows single-stage repair by placing antegrade endovascular ETG in the descending aorta under direct visualization during hypothermia (Preventza, 2013). |
| What is the advantage of using an ETG? | Serves as anchor for adjunct stent graft and prevents proximal endoleak |
| How is the ETG identified during the second stage endovascular repair? | 1. Four radiopaque clips at distal periphery of the graft<br>2. Pacing wires hang from the distal aspect of the graft |

## Indications/Contraindications

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| If proximal landing zone is <2 cm with the ascending aorta, what approach is indicated? | Zone 0 hybrid repair with Dacron graft placement for landing zone |
| What is the indication for elephant trunk technique? | Unable to rebuild proximal landing zone in an aneurysmal ascending (zone 0) and descending aorta pathology |
| What is the difference in treatment strategy between pathology affecting aortic zone 0 and aortic zones 1 through 3? | Pathology affecting zone 0 likely requires a sternotomy with debranching as it must be repaired with either open aortic arch replacement or a hybrid procedure (i.e., elephant trunk followed by TEVAR). Pathology affecting zones 1 through 3 frequently can be treated *without* a sternotomy or debranching with extra-anatomic bypasses to the cerebral vessels with subsequent TEVAR (Xydas et al.). |
| During zone 2 repair, the left subclavian artery is not always preserved. What are the absolute indications for LSA revascularization? | Dominant left vertebral artery or absent right VA<br>Patent left LIMA-LAD bypass<br>Left AVF/AVG for hemodialysis |
| What are the relative indications for LSA revascularization? | Prior LUE ischemia<br>Risk of spinal cord ischemia due to large stent graft (thyrocervical trunk feeds anterior spinal artery) |

## General Step by Step

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| What are the various arterial access options that can be performed for intervention? | Open: Vascular cutdown to the upper extremity or femoral arteries or retroperitoneal aortic exposure<br>Minimally invasive:<br>Femoral: US-guided standard Seldinger technique followed by percutaneous arteriotomy closure device (i.e., ProGlide Abbott Vascular, Redwood City, CA)<br>US-guided standard Seldinger technique for brachial access |
| If a patient has small-caliber external iliac arteries, when should a retroperitoneal exposure be considered? | When the device requires 24–26F access sheaths |
| What are the access requirements to perform a parallel grafting technique? | The minimal vessel diameter must accommodate on one side a conventional femoral approach 16–22F (for the main aortic device).<br>The contralateral femoral access minimal sheath size is highly variable by manufacturer and endograft type.<br>For the visceral vessel to be stented, an additional access for a 6–8 Fr sheath is typically required, targeted at the vessel of interest. |
| What steps must be considered when planning complex aortic repair? | Determining if the access arteries will accommodate large sheaths.<br>Prospective planning is needed to determine if exclusive percutaneous approach will be possible (availability of 2 femoral arteries +1 or 2 upper extremity) or surgical conduit needed.<br>Use of simulators or 3D printed models is growing in order to attempt to decrease procedural time and complications.<br>Meticulous analysis of measurements and aneurysm characteristics: proximal neck length, diameter, mural calcification, presence of thrombus, and angulation. |

## *Complex Abdominal Aortic Aneurysm (AAA)*

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| What additional step must be accounted for during preoperative AAA repair planning after the main body is deployed? | Plan cannulation of the contralateral gate. |
| How are the abdominal aortic endografts deployed? | The deployment of the main body and iliac branched endografts is specific to each manufacturer. However, once the snorkeled/chimney stents are in place in the visceral vessels, balloons are inflated at the same time in a kissing balloon fashion to form the final configuration. |
| What are the steps of a generic fEVAR procedure? | 1. Main aortic fenestrated graft (with visceral branch pre-cannulation or not[a])<br>2. Visceral branch covered stent deployment<br>3. Distal bifurcated stent graft device delivery<br>4. Iliac extension placement if needed |

[a]The aortic branch vessels can be pre-cannulated for alignment or after the fenestrated device is placed for delivering the covered stents

## *Complex TEVAR*

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| Where is the optimal position of the chimney graft in a TEVAR? | 2 cm beyond the thoracic endograft in the ascending aorta and at least 2 cm within the target vessel |
| Where is the optimal position of the periscope graft in a TEVAR? | Beyond 2 cm of the endograft to decrease the chance of an endoleak |

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| What artery is targeted for the side branch component of a branched endograft with a proximal landing in zone 2? | Left subclavian artery (LSA). If the landing zone is in zone 0 or 1, extra-anatomical bypass is needed to revascularize the left common carotid artery (LCCA) and/or LSA. |
| What is the advantage of having multiple sites of access when deploying a branched device? | The GORE TAG Thoracic Branch Endoprosthesis (TBE) can be deployed via common femoral access only. However, Hakim et al. advocate "through-and-through" access where an exchange wire is placed in the brachial artery (for zone 0 or 2 repair) or LCCA (in zone 1 repair) and snared through the CFA to help deploy the side branch, especially when the target vessel is angulated or tortuous. |

## *Hybrid: Open ± TEVAR*

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| What are the steps of a zone 1 hybrid repair? | 1. Carotid-carotid bypass anastomosis to mid left subclavian artery: Alternative: Left carotid-subclavian bypass and then snorkel LCCA as the stent excludes the vessel<br>2. Occlude the left common carotid artery and proximal LSA.<br>3. Retrograde deployment of endograft. |
| Why are the LSA and LCCA ligated (or coiled) during zone 1 repair? | To prevent type 2 and type 1 endoleaks, respectively |

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| What are the steps of a zone 0 hybrid repair? | 1. Left subclavian-carotid bypass<br>2. Debranching of LCCA and assess for cerebral ischemia via EEG with clamp test<br>3. Innominate artery debranching<br>4. Retrograde or antegrade deployment of endograft |
| How long is a typical clamp test performed during a zone 1 hybrid repair? | 3 min |
| When a patient with an ascending aortic aneurysm cannot undergo cardiopulmonary bypass, what technique is utilized for treatment? | Aortic wrapping with Dacron graft (Preventza, 2013) |
| What are the steps of a total thoracic aortic aneurysm repair? | 1. Modified Mt. Sinai technique: total arch replacement + Dacron elephant trunk<br>2. Snare pacing wires to prevent intussusception of endograft during retrograde deployment of endograft |

## Relevant Materials

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| What intraoperative support/monitoring can be used in complex aortic hybrid repairs? | Cardiopulmonary bypass<br>Spinal cord motor and sensory neurophysiologic monitoring<br>Transesophageal echocardiography<br>Electroencephalography (EEG) to monitor for signs of ischemic infarction during arch debranching (Zone 0 repair) |

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| During hemiarch replacement, what may be used to maintain cerebral perfusion? | Deep hypothermic circulatory arrest with either selective antegrade cerebral perfusion (SCAP) or retrograde cerebral perfusion (Preventza, 2013) |
| How is perfusion maintained with SCAP? | An arterial cannula allows bypass flow thru an 8 or 10 mm Dacron graft that is anastomosed to the right axillary artery allowing antegrade cerebral flow. |
| How is perfusion maintained in RCP? | Retrograde flow via bypass cannula in the SVC with goal central venous pressure of less than 20 mmHg. |
| What periprocedural support is needed if multiple fenestrations are planned during TEVAR? | ECMO. During in situ fenestration (ISF) via laser or ablation techniques, ECMO can be avoided if single-vessel ISF is performed promptly by an experienced operator. |
| When is preoperative lumbar drain placement indicated (Chisea)? | Ideally, a preoperative lumbar drain is placed in every TEVAR case, especially in the setting of:<br>1. Planned coverage of parent intercostal artery giving rise to the Adamkiewicz artery<br>2. Long-segment endograft spanning the native aorta[a]<br>3. Early postoperative spinal cord ischemia symptomatology<br>4. Previous or concomitant repair of infrarenal aorta<br>5. Occlusion the internal iliac arteries (reduced collaterals)<br>6. When the segment treated includes the thoracic aortic<br>7. Coverage of the left subclavian artery origin without revascularization<br>8. Renal failure |

[a]The length of the aortic segment treated is the most significant risk factor for the occurrence of spinal ischemia (The longer the segment, the higher the risk)

*Devices*

| Thoracoabdominal | Abdominal | Both | Branch stents |
|---|---|---|---|
| GORE TAG, C-TAG (W.L. Gore and Assoc., Flagstaff, AZ) | Zenith Fenestrated [ZFEN] (Cook Medical, Bloomington, IN) | GORE EXCLUDER Thora-coabdominal Branch Endoprosthesis (TAMBE) (W.L. Gore and Assoc., Flagstaff, AZ) | Atrium iCast (Atrium Medical, Hudson, NH, USA) |
| Medtronic Talent (Medtronic, Santa Rosa, CA) | Nellix EVAS (Endologix, Irvine, CA, USA) | Cook Zenith t-Branch (Cook Medical, Bloomington, IN) | Gore VBX (W.L. Gore, Flagstaff, AZ, USA) |
| Arch Branch (IDE) (Cook Medical, Bloomington, IN, USA) | GORE EXCLUDER Iliac Branch Endoprosthesis (IDE) (W.L. Gore and Assoc., Flagstaff, AZ) | Cook Zenith p-Branch (Cook Medical, Bloomington, IN) | |
| Zenith Alpha (Cook Medical, Bloomington, IN, USA) | | | |
| Zenith TX2 (Cook Medical, Bloomington IN) | | | |
| Relay stent-graft (Terumo Aortic, Sunrise, Fla) | | | |

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| What imaging is performed for postoperative surveillance? | CTA: 1, 6, 12 months, and yearly<br>US Doppler of fenestrated target visceral arteries 1, 6, and 12 months |
| What medications are prescribed status post complex aortic repair? | Plavix for 3 months and aspirin for lifetime |
| What should the clinical exam focus on after complex aortic repair? | Neurological: paresthesias, paralysis, and stroke<br>Cardiac: risk of perioperative myocardial infarction (< 30 days post-op)<br>Renal: function |

## Complications

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| What complications are seen with complex hybrid thoracic aortic repairs? | Paraplegia (Brat, 2018) and myocardial infarction |
| What are the mortality rates associated with complex hybrid thoracic aortic repairs? | Up to 30% (Brat, 2018)<br>Although, Zhao et al. and Kawaharada report rates as low as 4–6% after stented elephant trunk graft (ETG) |
| What are the most common post-op complications after zone 0 hybrid repair? | Stroke and retrograde type A dissection |
| What is the most common cause of death after zone 0 hybrid thoracic aortic repairs? | Retrograde type A dissection (RTAD) |

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| What are the risk factors of RTAD? | Native: Aneurysmal ascending aorta and existing dissection.<br>Iatrogenic: clamp injury during debranching and device injury.<br>Environmental change: alternate anatomy leads to hemodynamic change of blood flow and tissue mismatch between graft and native aorta. |
| What eliminates the risk of retrograde type A dissections? | Use of Dacron ascending aortic graft. Stent-assisted coil placement (SACP) decreases the risk of RTADs and neurological complications after complex thoracic aortic repairs (Xydas, 2015). |
| Which complex thoracic repair is associated with highest mortality at 30 days? | Zone 0; 1-year survival is similar for all types of repair however at ~25%. |
| What is the most common type of endoleak after ETG complex thoracic repair? | Type 2 (Brat, 2018) |
| What is the most common type of endoleak with fEVAR? | Hakim et al. report type 1c, which they treat with coil embolization. However, according to the Zenith trial, which examined only ZFEN stent grafts, no endoleaks were reported in that study. |

## Landmark Research

Andersen ND, Williams JB, Hanna JM, Shah AA, McCann RL, Hughes GC. Results with an algorithmic approach to hybrid repair of the aortic arch. *Journal of Vascular Surgery*. 2013;57(3):655–667. https://doi.org/10.1016/j.jvs.2012.09.039

- This study demonstrated ascending aorta zone 0 endograft placement to be a univariate predictor of 30-day in-

hospital mortality after complex hybrid thoracic aortic repairs.

- Developed an algorithm for stratifying complex thoracic aortic repair. The study examined 87 patients who underwent zone 1 endograft coverage with extra-anatomic left carotid revascularization ($n$ = 19), zone 0 endograft coverage with aortic arch debranching ($n$ = 48), or total arch replacement with staged stented elephant trunk completion ($n$ = 20). Their data demonstrated high rates of retrograde type A dissections leading to higher 30-day periprocedural mortality in patients who had grafts placed in zone 0.
- Currently, there is no FDA-approved thoracic endograft for labeled use in zone 0. Current investigations are underway examining the effectiveness and safety of novel thoracic endografts in zones 0–2.

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| Which chEVAR registry observed the most common endoleak type in the intraprocedural setting, as well as the factors associated with it? | The Pericles Registry (898 chimney grafts) observed intraoperative type Ia endoleak in 41 patients (7.9%), which only remained present in 2 patients on follow-up imaging. Intraoperative type Ia endoleak can be minimized with landing zone >20 mm, prolonged kissing balloon inflation, or additional cuff placement. |
| Which publication contains the most extensive data analysis comparing outcomes of FEVAR vs. chEVAR? | Yu Lie et al. – Systematic review and pooled data analysis of FEVAR vs. chEVAR compared outcomes for juxtarenal aortic aneurysms (JAA) for endoleak type I (3.7–7.6%), 30-day mortality (1.1% vs. 3.8%), and all-cause mortality (6.46% vs. 13.3%). |

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# Part IV
# Oncology

# Chapter 33
# Hepatic Interventional Oncology

**Seth I. Stein**

## Evaluating Patient

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| What are the most essential labs required to workup for possible liver-directed therapy? | Depending on the primary indication and procedure, common labs include albumin, bilirubin, platelet count, INR, alpha-fetoprotein (AFP), carcinoembryonic antigen (CEA), and eGFR. |
| What is the serum bilirubin level at which arterial embolotherapy is generally contraindicated? | Bilirubin >3 mg/dL (if segmental treatment can be performed, a higher bilirubin level may be acceptable) |
| Why are hepatic embolotherapies avoided in patients with diminished functional liver reserve and liver failure? | Ischemic insult of the procedure can worsen liver function. |

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| How is lung shunt fraction (LSF) calculated and why is it relevant for TARE? | LSF is calculated by delivering Tc99m-MAA to the intended treatment vessel during the mapping angiographic procedure and subsequently performing planar nuclear scintigraphy and/or SPECT/CT. Borderline (i.e., 10–20% LSF) or elevated LSF may necessitate dose reduction or preclude TARE altogether. Absolute dose to the lung >30 Gy per treatment or >50 Gy over time is considered more relevant to avoiding the risk of radiation pneumonitis. |
| How is liver reserve/cirrhosis mortality determined? | The Child-Pugh scoring system utilizes clinical factors and laboratory values to estimate cirrhosis mortality:<br>Useful for selecting the appropriate liver-directed therapy.<br>Factors include INR, encephalopathy, bilirubin, albumin, and ascites, which combine to classify patients into three categories:<br>Class A = Score 5–6<br>Class B = Score 7–9<br>Class C = Score 10–15 |

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| How is performance status classified? | The ECOG (Eastern Cooperative Oncology Group) performance status is utilized to further classify patients into the appropriate treatment option based on the following scale (ECOG 0–2 is required for most interventional treatments):<br>ECOG 0 → Fully active<br>ECOG 1 → Restricted in physically strenuous activity. Able to do light house or office work<br>ECOG 2 → Self-care okay. No work. Up/about >50% of waking hours<br>ECOG 3 → Limited self-care, confined to bed or chair >50% of waking hours<br>ECOG 4 → Completely disabled. No self-care. Confined to bed or chair<br>ECOG 5 → Dead |
| What is the BCLC staging system? | The Barcelona Clinic Liver Cancer (BCLC) staging system is a guideline created for the staging of HCC, considering the ECOG performance status (PS), Child-Pugh (CP) staging, and radiologic extent of disease. |
| What is the standard preprocedural imaging that should be performed before liver-directed therapy? | Three- or four-phase liver CT or MRI to assess anatomy, extrahepatic tumoral supply, and presence of ascites. Additional imaging may be performed to exclude extrahepatic disease. |

## High Yield History

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| What are the major risk factors for the development of HCC? | Hepatitis B, hepatitis C, alcohol use, NASH, hereditary liver diseases (e.g., hemochromatosis), and primary biliary cirrhosis |
| What is the latency period of HCC? | 1–3 decades |
| What is the 3-year survival of HCC if untreated? | 28% |
| After imaging evaluation is performed confirming HCC or hepatic metastases, which parties determine the appropriate treatment? | A multidisciplinary team or tumor board consisting of hepatobiliary surgery, interventional radiology, diagnostic radiology, radiation oncology, hepatology, medical oncology, and other specialties may be involved in such cases. |

## Indications/Contraindications

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| What are the Milan criteria for liver transplantation? | 1 tumor $\leq$ 5 cm, or up to 3 tumors $\leq$ 3 cm<br>No vascular invasion<br>No extrahepatic extension |
| What are the UCSF criteria? | Higher threshold for transplantation than Milan criteria<br>1 tumor $\leq$ 6.5 cm or 2 lesions $\leq$ 4.5 cm with a total tumor diameter $\leq$ 8 cm |
| What are the main indications for percutaneous ablation? | Favored for small isolated HCC (BCLC 0 and BCLC A disease).<br>Data shows equivalent survival for thermal ablation and surgical resection in this group.<br>Resection is often preferred if tumor is in a location difficult to get good ablative margins (e.g., hepatic dome). |

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| What are the common reasons to perform ablation over hepatic resection? | Thermal and/or radiative ablation is often utilized if mass is deemed unresectable and there are poor liver function, multifocal disease/metastases, or comorbidities negating surgical treatment.<br>Ablation is less invasive, causes less pain, and results in less complications, as well as a shorter hospital stay.<br>Ablation can be performed as a bridge to transplantation. |
| What areas are generally avoided in percutaneous ablation? | < 1 cm to a central bile duct, hepatic dome or anterior exophytic lesions, adjacent to large high flow blood vessels, near gastric and bowel tissue, or near the gallbladder fossa |
| When is TACE utilized in the treatment of HCC? | Treatment of unresectable disease, including large tumors and multinodular disease without evidence of vascular invasion or extrahepatic spread |
| What are the common indications for TARE? | Advanced unresectable HCC with life expectancy > 3 months.<br>HCC with portal vein thrombosis.<br>Downstaging patients to resectable disease (similar to TACE), particularly in bilobar or multinodular disease (> 5 tumors).<br>Increase functional liver reserve with the goal of contralateral hypertrophy prior to resection.<br>Radiation segmentectomy in early stage disease.<br>Increasing use outside of HCC for hepatic metastatic disease. |
| What are the contraindications of TARE? | Child-Pugh C disease with marginal hepatic reserve (serum bilirubin greater than 3 mg/dL (except for segmental injection)) and ECOG > 2 |

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| When is TACE preferred over TARE? | TARE not universally available in the USA or worldwide<br>Patients susceptible to radioembolization-induced liver disease (REILD) or with hyperbilirubinemia<br>Tumor staining for thermal ablation |
| What is the benefit of adding TACE to ablation? | Added TACE to ablation in lesions larger than 3 cm, satellite tumors, those in precarious location, poorly encapsulated, or not well visualized on US or CT can improve outcomes.<br>Tumor staining with Ethiodol improves targeting for ablation.<br>Pre-ablation TACE increases ablation zones by diminishing heat sink effect.<br>Results in overall improved survival in tumors >5 cm. |
| Can targeted therapies be used for colorectal cancer liver metastases? | TARE is considered the best initial intra-arterial locoregional therapy in treating CRC metastases. Drug-eluting beads loaded with irinotecan (DEBIRI) have also demonstrated improved overall survival. |
| What is radiation segmentectomy? | Selective transcatheter delivery of Y-90 is delivered to two segments or less, with ablative intent |

## Relevant Anatomy

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| Why can arterial embolization procedures be performed largely without causing liver necrosis and liver failure? | This is due to differences in the blood supply to normal liver versus tumors. 80% of tumors are supplied by the hepatic artery. 70–75% of normal liver parenchyma is supplied by the portal vein. |

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| How is nontarget anatomy protected during percutaneous ablation? | Patient positioning, general anesthesia with a paralytic to control breathing, chilled fluids through biliary system, intentional pneumothorax, intraperitoneal gas, fluid, or balloons |
| Describe the normal hepatic arterial branch pattern from celiac trunk. Approximately what percentage of people have this anatomy? | The celiac trunk normally trifurcates into splenic, left gastric, and common hepatic arteries. The common hepatic artery then bifurcates into the gastroduodenal artery and proper hepatic artery. The proper hepatic artery then gives rise to the left and right hepatic arteries. The middle hepatic artery, which supplies the caudate lobe, most commonly arises from either the left or right hepatic artery, although in 10% of cases may originate directly from the proper hepatic artery. |

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| What are the most frequently observed hepatic artery variants? | "Replaced" means the hepatic artery in its entirely arises from the variant origin, whereas "accessory" means the hepatic artery is duplicated in that there is a branch arising from the normal origin, as well as an accessory branch that arises from the aberrant origin.<br>Common hepatic artery off aorta or SMA, or trifurcation into right hepatic, left hepatic, and GDA<br>Replaced left hepatic artery from left gastric artery<br>Accessory left hepatic artery from left gastric artery<br>Replaced right hepatic artery from the SMA, celiac trunk, or aorta<br>Accessory right hepatic artery from the SMA<br>A replaced or accessory right hepatic artery typically originates from the superior mesenteric artery, whereas a replaced or accessory left hepatic artery typically originates from the left gastric artery.<br>Combinations of these variants occur, for instance a patient may have both replaced left and right hepatic arteries, or may have a replaced artery on one side and an accessory artery on the other, although these cases are exceedingly rare (<5%). |
| After multiple TACE procedures, what anatomical considerations are important to consider? | Development of extrahepatic collateral vessels (i.e., right and left internal mammary, right and left inferior phrenic, right and left gastric arteries) is common (~25% of TACE). |

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| How is cone-beam CT (CBCT) utilized during hepatic arterial oncologic interventions? | Accurate anatomic localization of tumor-feeding arteries, following delivery of chemoembolic agent to ensure adequate territorial coverage, and to calculate of liver treatment volumes for TARE |
| Why is mapping procedure required prior to Y-90 radioembolization? | The mapping procedure is performed to delineate tumoral blood supply. Both celiac and SMA arteriograms are performed, as well as selective injections with or without the use of cone-beam CT. Once the treatment territory is confirmed, Tc99-MAA is delivered via the microcatheter. After the procedure, planar nuclear imaging is performed to calculate lung shunt fraction. SPECT/CT is sometimes performed, and can be used to assess for nontarget delivery in the abdomen/pelvis. |
| What are the essential vessels to identify during the mapping procedure? | Cystic artery, right gastric artery, gastroduodenal artery, pancreaticoduodenal arcade, falciform artery, and any additional feeders to hepatic tumors (i.e., inferior phrenic artery) |

## Relevant Materials

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| When is percutaneous ethanol ablation employed? | This historical agent is an inexpensive option utilized for smaller tumors near heat-sensitive organs. |

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| How does radiofrequency ablation (RFA) treat tumors and what are its limitations? | RFA is a widely utilized method of thermal ablation that induces coagulative necrosis. Its survival benefit versus ethanol ablation is most pronounced in tumors larger than 2 cm, and can be used for tumors up to 3 cm. It has fallen out of favor in some institutions due to limitations of heat sink effect from nearby vessels and the availability of microwave ablation. |
| What is microwave ablation and what are its benefits? | Microwave ablation produces oscillation of water molecules, friction, and thus very high temperatures, resulting in coagulative necrosis in tumoral tissue. It has replaced RFA in many institutions because it can heat tissue faster, multiple probes can be utilized simultaneously to achieve larger ablation zones, and it is less susceptible to heat sink effect. |
| How does cryoablation work and what are its advantages? | Cycles of freezing and thawing disrupt cell membranes of tumor cells (lysis) inducing cell death. It is less painful for patients than microwave ablation, though it is less commonly utilized for liver-directed therapy. The ablation zone (ice ball) can be actively visualized on intraprocedural imaging, helping to confirm adequate coverage of the desired treatment target. |
| What is a dreaded complication of cryoablation? | Cryoshock is an extremely rare complication of cryoablation caused by cytokine release, which can lead to disseminated intravascular coagulation (DIC) and multi-organ failure. |

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| What is irreversible electroporation (IRE) and when is it utilized? | This is a nonthermal technique utilizing high-energy electrical pulses to disrupt cell membranes and cause cell death. IRE must be performed under anesthesia with a neuromuscular blocking agent and cardiac monitor to avoid muscle contractions and arrhythmias. The benefit is the ability to safely be utilized for small tumors near blood vessels and bile ducts due to its nonthermal mechanism and lack of heat sink effect. |
| What is "bland embolization"? | Mechanical obstruction using embolic agent without the use of a chemotherapeutic agent |
| What is ethiodized oil and why is it effective? | Embolic agent also utilized as a carrier of chemotherapeutics<br>Contains iodine, easily identified on imaging<br>Attaches to the cancer cell membrane of liver tumors and travels via the peribiliary capillary plexus to the portal branches, thereby depleting nutrient supply to potential nonimaged satellite lesions. |
| What is the typical chemotherapeutic dosing for conventional TACE? | Variable; single or multiple drug regimens may be used. A common regimen includes 50–100 mg cisplatin, 50–75 mg doxorubicin, and 10 mg mitomycin C. The drugs are mixed with contrast to improve visualization on imaging and to stabilize the drug/oil emulsion. |
| How much ethiodized oil should be administered in TACE? | The ratio of volume of drug to oil should be 1:2.<br>Ethiodized oil volume is tumor dependent, typically less than 15 mL per session. |

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| What should be administered intra-arterially after chemotherapeutic/ethiodized oil emulsion? | Embolic material such as particles or gel foam prevents washout of ethiodized oil from the treated zone. |
| What is DEB-TACE and what are its purported benefits over conventional TACE? | Drug-eluting beads lodge in small tumoral arterioles, delivering a sustained release of chemotherapy.<br>Reduced liver toxicity and potential systemic uptake.<br>Consistency and reproducibility of treatment. |

## General Step by Step

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| What preprocedural imaging should ideally be performed prior to ablation procedures? | CT or MRI within 2 weeks for colorectal cancer metastases and 2–4 months for HCC |
| What intraprocedural imaging is performed for ablation? | CT and ultrasound are most frequently utilized for both probe/applicator placement and monitoring the ablation zone. MRI can also be utilized if available and probes are compatible. Ultrasound and CT can be utilized to monitor ice ball formation during cryoablation. After the procedure, contrast-enhanced CT, MRI, or ultrasound is performed to confirm adequate ablation zone. |
| What are acceptable ablative margins for HCC and for liver metastases? | Circumferential ablation zone of 0.5 cm for HCC and 1.0 cm for metastases |

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| What microwave ablation technique is utilized for larger tumors or those with insufficient margins? | Synchronous ablation utilizing multiple overlapping probes |
| How are ablation patients typically monitored post-procedurally? | Monitored for pain and discharged with pain medications.<br>If necessary, the patient may be admitted overnight for pain control. |
| What medications may be given prior to TACE? | Variable. Some use a combination of antiemetics, steroids, diphenhydramine, and/or antibiotics. |
| When are preprocedural prophylactic antibiotics indicated for TACE? | Controversial. Some prescribe antibiotics both 2–3 days before and for 2–3 weeks following the procedure in patients with increased risk of developing a liver abscess (prior biliary interventions). |
| What vessel should be interrogated after aortography to assess for accessory or replaced hepatic arteries? | SMA |
| What vessels are commonly interrogated, and what are their common injection rates for hepatic arterial interventions? | Aorta: 15–20 mL/s for 30–40 mL<br>SMA: 3–5 mL/s for 12–30 mL<br>Celiac: 3–4 mL/s for 12–15 mL<br>Common hepatic artery (CHA): 3 mL/s for 12 mL<br>Gastroduodenal artery (GDA): 2 mL/s for 8 mL<br>Proper hepatic: 3 mL/s for 12 mL<br>Left hepatic: 2 mL/s for 8 mL<br>Right hepatic: 2 mL/s for 10–12 mL<br>Phrenics: 1–2 mL/s for 4–6 mL |

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| Once the hepatic tumoral supply is identified, what maneuver is necessary prior to delivery of chemoembolic emulsion? | A microcatheter (2–2.8 Fr) should be used to obtain selective access for segmental/subsegmental treatment. |
| How should the patient be managed immediately following TACE? | Aggressive IV hydration, pain control, such as with patient-controlled analgesia (PCA), and antiemetics |
| How is imaging response to TACE monitored? | Contrast-enhanced CT or MRI ~ 4 weeks after the procedure.<br>If there is no residual viable disease, follow-up imaging should be performed every 2–3 months. |
| Which medications should be administered for TARE? | PPI or H2 blocker 1 week prior and for 4 weeks following procedure<br>Nausea medication such as ondansetron day of procedure<br>+/− steroids for postembolization syndrome<br>+/− empirical antibiotics for biliary tract infection<br>+/− oral analgesics |
| What is the dose of 99mTc-MAA delivered during the mapping study? | Approximately 4–5 mCi |
| Why is it essential to calculate “lung shunt fraction?” | 30 Gy delivered per session or 50 Gy cumulatively to the lungs has been shown to induce radiation pneumonitis. |

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| What are the dose reduction parameters for patients with lung shunting demonstrated on mapping study? | < 10% → no dose reduction.<br>10–15% → 20% dose reduction.<br>15–20% → 40% dose reduction.<br>> 20% → radioembolization is contraindicated (with the caveat that it may be performed in rare cases that total absolute dose to the lung is less than 30 Gy in a single session or 50 Gy over multiple sessions). |
| What imaging can be performed to document Y-90 deposition in tumoral tissue? | Bremsstrahlung SPECT scan within 24 h of TARE<br>Newer modality time-of flight PET-CT |

## Complications

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| How are patients protected from ablation of sensitive nontarget tissue? | Hydrodissection with 5% dextrose or sterile water can create a plane between the ablation zone and nontarget tissue. |
| What is the risk of tumor seeding from RFA? | 0.2–2.8% with risk factors including high AFP, undifferentiated HCC, subcapsular lesions, and multiple needle insertions |
| Which patients are most at risk for liver abscess following liver-directed therapy? | Prior biliary intervention |
| What is postembolization syndrome? | Fever, abdominal pain, nausea, and vomiting following an embolization procedure |
| What is a commonly utilized intraprocedural practice to control pain from visceral embolization? | Administer intra-arterial lidocaine prior to delivery of the chemoembolic emulsion and between aliquots. |

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| What potential life-threating complications exist from administering too much ethiodized oil in TACE? | Pulmonary embolism from hepatovenous shunting to the lungs and liver failure |
| How does the side effect profile of TARE compare to TACE? | TARE patients also may develop constitutional symptoms including fatigue, abdominal pain, and nausea. However, symptoms are usually not as severe or immediate but can be prolonged. |
| What are the complications of TARE? | Radiation pneumonitis, radioembolization-induced liver disease (REILD), liver toxicity, GI ulceration, gastritis, skin irritation, and cholecystitis |
| Where should TARE be performed relative to the cystic artery? | Distal to the cystic artery |
| How does REILD present and how is it managed? | Can present up to several months following TARE<br>Laboratory: elevated bilirubin and decreased albumin<br>Clinical: ascites<br>Imaging: hepatic perfusion abnormalities (veno-occlusive disease)<br>Treatment: depends on severity, may include diuretics, high-dose steroids, sustained low-dose heparin, ursodeoxycholic acid, and pentoxifylline |
| What measures are taken to avoid REILD when performing bilobar whole liver TARE or when prescribed activity is high? | Dose reduction strategies or sequential sessions/fractionation to each lobe separated by 1-month dosing to single lobe |

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| How are patients protected from "nontarget embolization" in TARE? | Prophylactic coiling or gel foam embolization of potential nontarget arterial branches |

## Landmark Research

### *Ablation*

Chen M-S, Li J-Q, Zheng Y, et al. A prospective randomized trial comparing percutaneous local ablative therapy and partial hepatectomy for small hepatocellular carcinoma. *Ann Surg*. 2006;243(3):321–8.

- RCT comparing percutaneous RFA with partial hepatectomy for early solitary HCC ≤ 5 cm.
- Ablation and resection for early HCC had similar 1-, 2-, 3-, and 4-year survival rates.
- Resection had statistically significant increase in complications related to surgery, longer hospital stay, and increased postoperative stay.

Loriaud A, Denys A, Seror O, et al. Hepatocellular carcinoma abutting large vessels: comparison of four percutaneous ablation systems. *Int J Hyperthermia*. 2018;34(8):1171–8.

- RCT in patients with BCLC stage 0 and A with perivascular HCC comparing monopolar RFA, cluster RFA, multi-bipolar RFA, and microwave ablation.
- Primary endpoint: overall long-term progression.
- Multi-bipolar RFA and cluster RFA provided better local tumor control than microwave ablation or monopolar RFA.

### *Conventional TACE*

Lo C-M, Ngan H, Tso W-K, Liu C-L, Lam C-M, Poon RT-P, et al. Randomized controlled trial of transarterial lipiodol

chemoembolization for unresectable hepatocellular carcinoma. *Hepatology*. 2002;35(5):1164–71.

- TACE vs. symptomatic treatment for unresectable HCC in Asian patients
- TACE with improved overall survival at 1, 2, and 3 years

Llovet JM, Real MI, Montaña X, et al. Arterial embolisation or chemoembolisation versus symptomatic treatment in patients with unresectable hepatocellular carcinoma: a randomised controlled trial. *Lancet*. 2002;359(9319):1734–9.

- TACE vs. bland embolization vs. symptomatic treatment for unresectable intermediate stage HCC in Caucasian patients.
- The study was stopped due to consistent results showing improved 1-, 2-, and 3-year survival of chemoembolization patients.
- TACE group showed lower rates of vascular invasion and lowest rate of death due to tumor progression, but the study stopped prior to establishing improved effectiveness compared to bland embolization.

## *DEB-TACE*

Lammer J, Malagari K, Vogl T, et al. Prospective randomized study of doxorubicin-eluting-bead embolization in the treatment of hepatocellular carcinoma: results of the PRECISION V study. *Cardiovasc Intervent Radiol*. 2010;33(1):41–52.

- Multicenter RCT with 1200 patients randomized to conventional TACE vs. drug-eluting bead treatment of HCC, with primary outcome of tumor response at 6 months.
- Demonstrated safety of DEB-TACE, unable to demonstrate superiority of DEB-TACE to conventional TACE.
- Subgroup analysis showed DEB-TACE with improved response in more advanced disease (CP B, ECOG 1) compared to conventional TACE.

- DEB-TACE with improved tolerability and decreased serious liver toxicity overall.

Lencioni R, Llovet JM, Han G, Tak WY, Yang J, Guglielmi A, et al. Sorafenib or placebo plus TACE with doxorubicin-eluting beads for intermediate stage HCC: the SPACE trial. *J Hepatol*. 2016;64(5):1090–8.

- RCT comparing DEB-TACE alone vs. DEB-TACE + sorafenib for intermediate stage HCC.
- Did not establish significant improvements in clinical outcomes for combination group as opposed to DEB-TACE alone.

## *Bland Embolization*

Brown KT, Do RK, Gonen M, et al. Randomized trial of hepatic artery embolization for hepatocellular carcinoma using doxorubicin-eluting microspheres compared with embolization with microspheres alone. *J Clin Oncol*. 2016;34(17):2046–53.

- Single-center RCT comparing bland embolization to DEB-TACE for the treatment of HCC.
- Included BCLC A, B, and C patients in both groups
- No difference in imaging response, progression-free survival, or overall survival between the two groups

## *Transarterial Radioembolization*

Salem R, Gordon AC, Mouli S, et al. Y90 radioembolization significantly prolongs time to progression compared with chemoembolization in patients with hepatocellular carcinoma. *Gastroenterology*. 2016;151(6):1155–63.

- RCT conventional TACE vs. TARE for BCLC A and B patients.
- Primary outcome: time to progression.

- TARE had a significantly longer time to progression (>26 months) than conventional TACE (6.8 months). Longer time to progression did not translate to increased overall survival.

Lewandowski RJ, Gabr A, Abouchaleh N, et al. Radiation segmentectomy: potential curative therapy for early hepatocellular carcinoma. *Radiology*. 2018;287(3):1050–8.

- Retrospective cohort study of BCLC stage 0 and A patients at single center with solitary HCC ≤ 5 cm treated with radiation segmentectomy (>190 Gy ablative dose).
- Median overall survival, 6.7 years; time to progression, 2.4 years.
- Response rates, tumor control, and survival comparable to other "curative" therapies such as thermal ablation, partial hepatectomy, and transplantation in early stage HCC.

Wasan HS, Gibbs P, Sharma NK, et al. First-line selective internal radiotherapy plus chemotherapy versus chemotherapy alone in patients with liver metastases from colorectal cancer (FOXFIRE, SIRFLOX, and FOXFIRE-Global): a combined analysis of three multicentre, randomised, phase 3 trials. *Lancet Oncol*. 2017;18(9):1159–71.

- Analyzed data from three trials to assess chemotherapy alone vs. chemotherapy + TARE with resin microspheres as first-line therapy for patients with liver-only colorectal cancer metastases
- Found that adding TARE improved liver-specific progression and radiological response, but did not improve overall or progression-free survival

Vilgrain V, Pereira H, Assenat E, et al. Efficacy and safety of selective internal radiotherapy with yttrium-90 resin microspheres compared with sorafenib in locally advanced and inoperable hepatocellular carcinoma (SARAH): an open-label randomised controlled phase 3 trial. *Lancet Oncol*. 2017;18(12):1624–36.

- Multicenter RCT in France comparing the use of sorafenib vs. TARE for patients with locally advanced stage (BCLC

stage C) or intermediate stage (BCLC stage B failing TACE) HCC.
- Primary endpoint: overall survival, which did not differ between the two groups.
- TARE patients had improved QOL, improved tumor response, and decreased adverse events (sorafenib can have many toxic side effects).

Chow PKH, Gandhi M, Tan S-B, et al. SIRveNIB: selective internal radiation therapy versus sorafenib in Asia-Pacific patients with hepatocellular carcinoma. *J Clin Oncol*. 2018;36(19):1913–21.

- Multicenter RCT in comparing the use of sorafenib vs. TARE for patients with locally advanced (BCLC stage B or C) HCC.
- Primary endpoint: overall survival, which did not differ between groups.
- TARE patients had fewer grade ≥ 3 adverse events than sorafenib; TARE patients had better tumor response rate.
- Key differences from SARAH trial (above): Single TARE (vs. SARAH with repeat TARE allowed), lower bilirubin level threshold (32 mmol/L vs. <=50 SARAH), lower proportion of BCLC C disease, and better survival in patients with BCLC C disease treated with TARE in SIRveNIB vs. SARAH.

## Common Questions

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| What is the goal temperature of RFA? | 60–100 °C (above 100 °C is less effective due to charring). |
| What is the primary model utilized to calculate activity for delivery of Y-90 resin microspheres? | Body surface area (BSA) model |

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| What is the primary model utilized to calculate activity for delivery of Y-90 glass microspheres? | Medical internal radiation dose (MIRD) |
| How long is the patient "radioactive" after TARE and what measures should be taken? | Y-90 has a 64-h half-life.<br>Patients should avoid close contact with pregnant women and children for 3 days. |
| What is the typical surface radiation dose from the patient after TARE? | < 1 mrem/h. |
| What is the goal future liver remnant (FLR) before surgical resection in patients with cirrhosis or chronic hepatitis? | ≥ 40% of the preoperative liver volume |
| What is portal vein embolization (PVE)? | Technique utilized to cause compensatory hypertrophy in the FLR.<br>PVE may increase FLR by 30%.<br>Takes 3–4 weeks to induce hypertrophy. |
| What is radiation lobectomy? | Delivery of Y-90 in a lobar fashion<br>Similar to PVE, causes compensatory hypertrophy to the contralateral lobe prior to resection<br>Can take longer than PVE to induce hypertrophy, but has the advantage of controlling the tumor(s) |
| What liver-directed therapies can be used to target early HCC? | Depending on liver transplantation candidacy and location, thermal ablation and radiation segmentectomy can be considered. |

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| What interventions are typically performed for asymptomatic large or multifocal HCC without evidence of vascular invasion or extrahepatic metastasis (intermediate stage HCC) (assuming good performance status and CP score)? | TACE +/− thermal ablation and TARE |
| What treatment options are available for symptomatic HCC with vascular invasion or extrahepatic spread (advanced stage HCC)? | Sorafenib and TARE |

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## Further Reading

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# Chapter 34
# Pulmonary Oncology

**John Smirniotopoulos and Maria Mitry**

## Evaluating the Patient

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| Do I need to evaluate the patient for a lung biopsy? | Every lung biopsy patient should have a formal evaluation by an interventional radiologist, and close inspection of cross-sectional imaging, as these patients have a risk of developing pneumothorax. |
| Are there particular considerations when consenting a patient for a lung procedure? | The most common complication of a lung biopsy or ablation is a pneumothorax. Therefore, it is good practice to not only explain that pneumothoraces are seen in up to 20% of these procedures but also consent the patient for a possible chest tube while consenting them for the main procedure. This will avoid any delay in placing such a tube should the patient require one urgently. |

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| What is clinically relevant? | Medical and surgical history with a focus on cardiopulmonary status, bleeding risk, and medications |
| Are there any adjustments to medications? | Prior to lung biopsy and ablation, anticoagulation should be discontinued. Inpatients currently taking warfarin can be transitioned to heparin infusion, which should be stopped 2 hours prior to the procedure for biopsy and 24 hours prior to ablation. |
| How recent should a chest CT be for a procedure? | Cross-sectional imaging of the chest (formal CT or PET/CT) should be obtained within 4 weeks of a procedure. |

## High Yield

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| What is the prevalence of lung cancer? | Lung cancer is the most common malignancy in the United States and worldwide, with 2.1 million new cases and 1.8 million related deaths in 2018. |
| What is the average age of diagnosis? | The majority of patients diagnosed with lung cancer are older than 65, with an average age of diagnosis of 70. |
| What is the gender difference? | The age-adjusted death rate for lung cancer is higher for men (46.7 per 100,000) than for women (31.9 per 100,000). |
| What are the risk factors? | Smoking is the main attributable risk to small-cell and non-small-cell lung cancers. |
| How much does secondhand smoke affect the risk of developing lung cancer? | Nonsmokers have a 20–30% greater chance of developing lung cancer if they are exposed to secondhand smoke at home or work. |

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| Does screening work? | Early detection, by low-dose CT screening, can decrease lung cancer mortality by 14–20% among high-risk populations. |
| What are the three types of lung nodules? | Solid: homogenous, soft-tissue attenuation nodules<br>Ground glass: hazy, nonuniform increased attenuation, does not obscure underlying vascular or bronchial structures<br>Part solid: both solid and ground glass components |
| What are the features of malignant nodules on imaging ? | Nodule size: >6–8 mm.<br>Nodule growth rate: assessed by volume doubling time (VDT). Malignant nodules can have VDT from 20 to 400 days, with VDT <100 days associated with the highest risk of malignancy.<br>Location: majority of malignancy is in the upper lobes.<br>Other features: spiculated margins, pleural indentation, vascular convergence, and/or air bronchograms. |
| What are the features of benign nodules on imaging? | Perifissural nodules are solid, smooth, and small (<10 mm) and are in contact with the pleural surface or fissure. Perifissural nodules often represent benign intrapulmonary lymph nodes.<br>Calcified nodules are often benign, although the pattern of calcification should be considered. Diffuse, central, lamellated, and popcorn calcifications are generally considered benign, whereas punctate, eccentric, and amorphous calcifications are indeterminate.<br>Intralesional fat suggests pulmonary hamartoma rather than malignancy. |

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| What are the most common types of lung cancer? What are some distinguishing features of each type? | Squamous cell carcinoma: typically centrally located, cavitary lesions, and most commonly associated with humoral hypercalcemia of malignancy (HHM)<br>Small-cell carcinoma: typically centrally located, poorer prognosis, and most commonly associated with hyponatremia from syndrome of inappropriate antidiuretic hormone secretion (SIADH), hypercortisolism from ectopic Cushing's syndrome (ECS), and proximal muscle weakness from Lambert-Eaton myasthenic syndrome<br>Adenocarcinoma: typically peripherally located, often ground glass, or part solid lesion |

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| How is non-small-cell lung cancer (NSCLC) staged? | TNM (tumor, nodes, metastasis) staging:<br>T:<br>T1: less than 3 cm<br>T2: 3–5 cm, involvement of the main bronchus ≥2 cm distal to the carina, invasion of visceral pleura, atelectasis, or obstructive pneumonitis extending to the hilum<br>T3: 5–7 cm and/or invades the chest wall (includes superior sulcus tumors), mediastinal pleura, or parietal pericardium, involves the main bronchus less than 2 cm distal to the carina, atelectasis or obstructive pneumonitis involving the whole lung, separate tumor nodule in the same lobe<br>T4: greater than 7 cm and/or invades the diaphragm, mediastinum, heart, great vessels, trachea, carina, recurrent laryngeal nerve, vertebral body, separate tumor nodule in a different ipsilateral lobe<br>N:<br>N0: No nodal metastases<br>N1: ipsilateral peribronchial and/or hilar nodes, direct extension to ipsilateral intrapulmonary nodes<br>N2: ipsilateral mediastinal and/or subcarinal nodes<br>N3: contralateral mediastinal or hilar nodes and/or ipsilateral or contralateral scalene or supraclavicular nodes<br>M:<br>M0: No distant metastases<br>M1: Distant metastases<br>Staging:<br>Stage I (A and B): Disease only in the lung, no nodal or distant metastases (T1 (A) or T2 (B), N0, M0)<br>Stage II (A and B): T1 N1 M0 (A) or T2 N0 M0, T3 N0 M0 (B)<br>Stage III (A and B):<br>A: T3 N1 M0, T1 N2 M0, T2 N2 M0, and T3 N2 M0<br>B: T4 N0 M0, T4 N1 M0, T4 T2 M0, T1 N3 M0, T2 N3 M0, T3 N3 M0, and T4 N3 M0<br>Stage IV: any T or N with M1 |

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| How is NSCLC treated? | Stage I: Surgery<br>Stage II: Surgery and adjuvant chemotherapy<br>Stage III: Surgery and adjuvant chemotherapy +/− radiation<br>Stage IV: Chemotherapy +/− radiation |
| What are the types of surgical treatments for NSCLC? | Standard treatment: lobectomy with mediastinal nodal sampling.<br>Segmentectomy and wedge resection:<br>Appropriate in patients with a nodule ≤2 cm and purely adenocarcinoma in situ on histology, ≥50% ground glass appearance, or long doubling time (>400 days)<br>Poor pulmonary reserve or major comorbidity that contraindicates lobectomy<br>Must be able to achieve surgical margins greater than or equal to 2 cm or the size of the nodule<br>Pneumonectomy: when lobectomy is insufficient for tumor removal (i.e., tumor crosses the fissure, involves hilar structures, such as pulmonary arteries/veins or mainstem bronchi). T3 or T4 tumors require en bloc resection of the involved structure with negative margins. |
| What makes lung cancer "inoperable"? What are the treatment options for these patients? | A tumor is inoperable if appropriate surgical resection (lobectomy, segmentectomy/wedge resection, or pneumonectomy) cannot be performed due to a patient's poor functional status or medical comorbidities, such as poor pulmonary reserve and cardiac disease. In these patients, definitive radiation therapy (stereotactic ablative radiotherapy, SABR) or image-guided thermal ablation may be appropriate definitive treatment methods. Further, in patients with invasive disease, if en bloc resection of involved structures with appropriate margins cannot be achieved, surgical management is not indicated. |

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| What are the challenges in treating superior sulcus (Pancoast) tumors? | Superior sulcus tumors are located in the apex of the lung and involve the apical chest wall and/or thoracic inlet structures. They are most commonly adenocarcinomas. By definition, all superior sulcus tumors are at least T3 and invade the chest wall and/or sympathetic chain. If there is no nodal involvement (T3 N0), superior sulcus tumors can be treated with chemoradiation followed by surgical resection. However, if there is invasion of vertebral bodies, brachial plexus, or vascular structures, the tumor is classified as T4. Because en bloc resection of invaded structures (i.e., vertebral bodies and/or subclavian vessels) is required, T4 superior sulcus tumors may be rendered inoperable even without nodal disease (stage IIIB). |
| What is the staging of small-cell lung (SCLC) cancer? | Limited stage: disease is confined to ipsilateral hemithorax, including regional lymph nodes, which can fit into a radiotherapy plan. Extensive stage: all other disease exceeding above boundaries, including contralateral disease involvement and distant metastases. |
| How is SCLC treated? | Chemoradiation therapy (not surgery) |
| What is the role of targeted therapy? | Development of lung cancers has been shown to be related to several genetic mutations, including those involving the VEGF, EGFR, ALK, ROS1, BRAF, RET, MET, and NTRK genes. Drugs that target cells with these types of mutations have been shown to be efficacious in the treatment of metastatic lung cancer, in some instances even improving overall survival when compared to traditional chemotherapy regimens. Immunohistochemical analysis of lung tumors can thereby elucidate additional therapies for patients. |

## Indications/Contraindications

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| When to biopsy? | Lung nodules > 8 mm, not amenable to endobronchial approach. Please note that this is highly variable from institution to institution. |
| What is the purpose of a lung biopsy? | To determine whether a pulmonary lesion is benign or malignant (i.e., new or enlarging mass) |
| Is there any benefit to biopsy of a nodule if it's not cancer? | A biopsy may be beneficial in determining infectious or inflammatory etiology of a lung nodule, as this will direct patient care and therapies, such as steroids for noninfectious or cryptogenic organizing pneumonia. |
| When to ablate primary lung cancer? | Early (stage I/II) primary non-small-cell lung cancer without lymph node involvement in nonsurgical candidates |
| When to ablate a metastatic lung nodule? | For palliation in nonsurgical candidates |
| What are the absolute contraindications to lung biopsy? | Pulmonary AVM or venous aneurysm/ abnormality, as these increase the risk of bleeding.<br>Inaccessible and/or a safer alternative is preferred.<br>Lung biopsy should not be considered in patients within 6 weeks of a myocardial infarction. |
| What are the relative contraindications to lung biopsy? | Fibrotic and emphysematous lung disease with multiple blebs and bullae<br>History of pneumonectomy of the non-affected lung<br>Uncorrected coagulopathy, unstable cardiopulmonary status, and pregnancy |

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| What are the contraindications for ablation? | Proximity to the hilum, large blood vessels, and bronchi<br>Bleeding diathesis, most relevant for cryoablation<br>Prior pneumonectomy<br>Unilateral functioning lung<br>Life expectancy of < 12 months<br>Acute pneumonia<br>Severe pulmonary arterial hypertension (> 40 mmHg)<br>Poor lung function (FEV1 < 1.0 L) |

## Relevant Anatomy

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| What are the relevant pleural layers in the lungs? | Parietal pleura: outer pleural layer, lines the inner chest wall.<br>Visceral pleura: inner pleural layer, lines the surface of the lungs. Decreasing the number of passes through the pleura during lung biopsy or ablation decreases the risk of periprocedural complications such as pneumothorax. |

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| What are the borders of the superior/ anterior/ middle/ posterior mediastinum, and what do they contain? | Superior mediastinum:<br>Superior border, thoracic outlet; inferior border, sternal angle; lateral borders, medial pleural sacs; anterior border, dorsal surface of manubrium; and posterior border, ventral surface of T1–T4 vertebral bodies<br>Contains: thymus, trachea, aortic arch, brachiocephalic trunk, left common carotid and brachiocephalic arteries, SVC, brachiocephalic veins, arch of the azygous vein, thoracic duct, left and right vagus and phrenic nerves, and recurrent laryngeal nerve<br>Anterior mediastinum:<br>Superior border, sternal angle; inferior border, diaphragm; lateral borders, medial reflections of the pleural sacs; anterior border, sternum; and posterior border, pericardium<br>Contains: thymus, internal thoracic arteries and veins, and parasternal lymph nodes<br>Anterior junction line: below the level of the carina<br>Middle mediastinum:<br>Superior border: sternal angle; inferior border: diaphragm; lateral borders: medial reflections of the pleural sacs; anterior and posterior borders: pericardium<br>Contains: heart, ascending aorta and great vessels, SVC/IVC, pulmonary trunk, trachea and main bronchi, phrenic nerve, vagus nerve, and sympathetic nerves<br>Posterior mediastinum:<br>Superior border, sternal angle; inferior border, diaphragm; lateral borders, pleural reflections; anterior border, pericardium; and posterior border, T5–T12 vertebral bodies<br>Contains: esophagus, descending thoracic aorta, azygous and hemiazygos veins, thoracic duct, vagus nerve, splanchnic nerve, and sympathetic nerves<br>Posterior junction line: above the level of the aortic arch |

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| Where do the primary and accessory neurovascular bundles lie? How does this affect percutaneous approach? | Intercostal veins, arteries, and nerves run along the inferior margin of the ribs, with the nerves coursing most inferiorly. Therefore, percutaneous approach should be along the superior margin of the inferior rib in the region of interest. |
| What are the pertinent vascular structures to pay close attention to? | Chest wall vasculature, such as the internal mammary and intercostal vessels and the subclavian and intrapulmonary vessels |
| What is the branching pattern of the right and left mainstem bronchi? | Right: the right main bronchus branches in the mediastinum; the right upper lobe bronchus is behind and below the right pulmonary artery (eparterial – arises above where the right pulmonary artery crosses the right main bronchus).<br>Left: the left main bronchus courses below the left pulmonary artery before branching into the left upper lobe bronchus (hyparterial – arises below where the left PA crosses the left main bronchus). |
| How can pulmonary arteries and veins be distinguished? | At the hilum, the superior pulmonary veins are anterior and inferior to the pulmonary arteries. In the lungs, the pulmonary veins course through the intersegmental septa (not adjacent to bronchi), whereas the segmental pulmonary arteries course adjacent to the corresponding bronchi. |

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| What are the major intrathoracic lymphatic structures and their location? | The thoracic duct is located in the posterior mediastinum and provides lymphatic drainage from the abdomen, bilateral lower extremities, left hemithorax, left upper extremity, and left face/neck. Can be idiopathic, malignant, or traumatic (damaged during intrathoracic surgery), and can result in chyle leaks, including chylothorax. May be managed with nonfat diet, surgery, or thoracic duct embolization. |
| What is the anatomy of the azygos/hemiazygos system? | Azygos vein: originates at the junction of the right ascending lumbar and subcostal veins, enters the chest at the aortic hiatus, courses through the posterior mediastinum, and empties anteriorly into the SVC at the level of T5–T6 (anterior to right main bronchus)<br>Hemiazygos vein: originates at the junction of the left ascending lumbar and subcostal veins, enters the chest at the aortic hiatus, and crosses midline to join the azygos vein at the level of T8–T9, posterior to the aorta |
| What would a persistent left-sided SVC (PLSVC) and total anomalous pulmonary venous return (TAPVR) look like? How are they differentiated/what are they associated with? | PLSVC: most commonly drains into the coronary sinus (associated with unroofed coronary sinus), usually not seen on chest X-ray unless catheter is present, may see widened shadow of the aorta, "half-moon" opacity from left of aortic arch to middle of left clavicle. Often it co-occurs with a right SVC. It is associated with other anomalies such as anomalous pulmonary veins, coarctation of the aorta, tetralogy of Fallot, transposition of the great vessels, and dextroversion.<br>TAPVR: all pulmonary veins drain directly to the right atrium. "Snowman sign" on chest X-ray reflects dilated vertical vein on the left with a dilated right atrium. It is associated with other cardiac anomalies and heterotaxy. |

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| What are some important radiographic signs for masses? | Hilar overlay: if hilar opacity obscures hilar structures, abnormality is within the hilum. If hilar structures are visible, abnormality is either anterior or posterior to the hilum.<br>Cervicothoracic sign: distinguish if a mediastinal mass is anterior (ill-defined superior border, in contact with soft tissue of the neck at or below the clavicle) or posterior (well-defined superior border since the posterior lung extends above the clavicle). The upper border of an anterior mediastinal mass cannot extend above the level of the clavicles.<br>Incomplete border: distinguish if mass is pleural/extrapleural versus intrapulmonary. Intrapulmonary masses are surrounded by the lung, so complete borders can be visualized, whereas extrapulmonary mass borders are not well delineated where they extend to the pleura/chest wall. |

## Relevant Materials

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| What do I need for a lung biopsy? | A coaxial system is often used, even for fine needle aspiration (FNA). Typically, a 17 or 19 gauge coaxial needle is appropriate with biopsy needle included in the kit, and 20–22 gauge hollow needles with 10 cc syringes for aspiration. |
| What are the types of ablation modalities? | 1. Microwave ablation<br>2. Radiofrequency ablation (RFA)<br>3. Cryoablation |
| Is one ablative tool superior over another? | If the nodule is < 3 cm, differing modalities are equally efficacious (RFA = microwave = cryo).<br>If the nodule is > 3 cm, then microwave > cryo > RFA. |

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| Does location play a role in the type of ablation probe? | If the nodule is within 1.5 cm of the pleura, all modalities are equally efficacious. |
| What may contribute to suboptimal ablation? | Heat sinks such as bronchi and adjacent vasculature |
| If there is concern for a heat sink, is one ablation probe superior? | Similar to nodules > 3 cm, if there is concern for heat sink, microwave > cryo > RFA. |
| The patient has a pacemaker/ICD/ LVAD. Does that matter? | For pacemakers and other implantable cardiac devices, cryo > microwave > RFA |

## General Step by Step

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| Lung biopsy | 1. Position the patient, preferably prone for a posterior approach. Lateral decubitus positioning (biopsy side down) may help prevent pneumothorax.<br>2. Apply guiding template or laser grid (if possible); use CT to mark the point of entry.<br>3. Sterilize and anesthetize site, including parietal pleura.<br>4. Use CT guidance to advance and confirm position of coaxial/core biopsy needle.<br>5. Obtain FNA/core biopsy samples.<br>6. If there is concern for a pneumothorax, administer 1–3 cc of patient blood for blood patch, or other device such as BioSentry, through the outer coaxial needle.<br>7. Remove the coaxial needle.<br>8. CT of the entire chest to rule out pneumothorax. |

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| Lung ablation: | 1. Position the patient, preferably prone for a posterior approach.<br>2. Securely apply grounding pads to the opposite chest wall if RFA.<br>3. Apply guiding template or laser grid (if possible); use CT to mark the point of entry.<br>4. Sterilize and anesthetize site, including parietal pleura<br>5. Use CT to advance applicator(s).<br>6. Confirm position of applicator(s).<br>7. Apply energy to achieve tumor necrosis with a 1 cm margin of normal lung parenchyma.<br>8. Remove applicator(s).<br>9. CT of the entire chest to rule out pneumothorax and estimate area of ablation. |
| Sometimes the pleura is transversed twice through a longer trajectory. Why? | Occasionally, due to complexity of a nodule location, inability to position the patient appropriately, or a combination of the two, a fissure must be crossed for a biopsy to be performed successfully. Therefore, the pleura of more than one lobe is crossed, leading to a technical passage of four layers of pleura. |
| Do I need additional post-procedure imaging? | One or two chest radiographs should be obtained post-procedure depending on your institution.<br>Typically, a chest radiograph is obtained immediately after the procedure and then 2 hours following the procedure. |
| The patient is having increased shortness of breath post-biopsy. What do I do? | If there is increasing pain or shortness of breath, repeat a chest radiograph to assess for pneumothorax. |

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| The patient is complaining of worsening chest pain post-biopsy: | 1. Monitor vitals, increase supplemental oxygenation, and draw labs for potential blood loss (Hb, Hct).<br>2. Oral analgesics for moderate pain (most situations).<br>3. PCA pumps or oral narcotics if severe/increasing pain.<br>4. NSAIDs for 3–5 days following discharge to limit pleural inflammation, thereby limiting pain and risk of pleural effusion. |

## Complications

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| What can go wrong? | Complications in lung ablation include post-ablation syndrome, mild pyrexia, pneumothorax, hemorrhage, hemoptysis, bronchopleural fistulas, ARDS, and damage to the surrounding skin (cellulitis) or abscess formation. |
| What if the patient has pain at the puncture site? | Look at incision sites to ensure absence of bleeding, or cellulitis (erythema (red), hyperemia (warm to touch), purulence, dolor (pain), and tumor (swelling)):<br>If there is no evidence of cellulitis – treat with analgesics.<br>If there is concern for cellulitis – consider adding antibiotics (cefazolin). |

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| What do I need to know about pneumothoraces and lung biopsies/ablations? | This may occur in up to 25% of patients, though not all pneumothoraces are treated the same way.<br>If the pneumothorax is small, repeat a chest X-ray to ensure stability. If the patient is asymptomatic, they can likely be discharged without additional intervention.<br>4–12% of pneumothoraces will require a chest tube, which also includes Heimlich valve chest tubes (patients can be discharged home with this type of tube).<br>20% of pneumothoraces after ablation resolve following evacuation of air with a small needle or catheter. |
| What is the risk of pleural effusion? | Pleural effusion after ablation may occur in 6–19% of patients. Most resolve spontaneously and rarely require thoracentesis or chest tube. |
| What is the risk of hemoptysis? | Hemoptysis may occur in up to 15% of patients, though it is often self-limited and does not require admission to the hospital. |
| What factors influence severe pulmonary hemorrhage or hemothorax? | Incidence is correlated with biopsy or ablation in close proximity to the hilum. |
| What should I do if there is concern for severe hemorrhage? | Obtain a stat CTA and prepare for endovascular or surgical intervention. |
| What is post-ablation syndrome (within 24–48 hours)? | Flu-like symptoms that develop within the first 24–48 hours of the procedure. Explain to the patient that they may experience fever, malaise, chills, myalgia, and nausea. Productive cough with rust-colored sputum may also occur. |

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| Does post-ablation syndrome require treatment? | This is typically self-limited, and may last up to 7–14 days. |
| Are there other less common complications to be aware of? | Infection, bronchopleural fistula, tumor seeding, and air embolism |

## Landmark Research

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## Common Questions

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| What follow-up do post-lung ablation patients require? | Non-contrast/contrast chest CT at 1 month<br>Chest CT at 4 months<br>FDG-PET/CT at 6 and 12 months<br>Followed by PET/CT or contrast CT at 6-month intervals |

## Further Reading

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# Chapter 35
# Renal Oncology

**Shaji Khan and Monica J. Uceda**

## Evaluating Patient

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| What are the most common types of renal malignancies? | RCC, lymphoma, urothelial cell carcinoma, and metastasis. Of these, RCC is the most common. |
| Why has the incidence of RCC increased over the past decade? | Detection rates of RCCs have increased with increasing use of radiologic imaging, as well as prevalence of smoking and obesity. |
| What are some symptoms of RCC? | Symptoms of RCC are nonspecific and may include abdominal or flank pain, anemia, fever, hematuria, a palpable lump, and weight loss. |

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| What is the differential diagnosis for an RCC on imaging? | A renal mass should be suspicious for malignancy until proven otherwise. Differential diagnoses include angiomyolipoma (AML) or oncocytoma, renal abscess, hematoma, lymphoma, metastasis, and a complex cyst. |
| What are some subtypes of RCC? | Clear cell (most common, 70%), papillary (10–15%), chromophobe (< 5%), and medullary (rare) |
| What are imaging features of the different RCC subtypes? | Clear cell: High T2 with microscopic fat (loses signal on out of phase); heterogenous and avidly enhancing |
| | Papillary: Low T2 and may contain hemosiderin (loses signal on in-phase); slow homogenous enhancement (hypovascular) |
| | Chromophobe: Typically low T2, commonly with calcifications; intermediate vascularity; may have stellate scar/spoke-wheel enhancement similar to oncocytoma |

## High Yield History

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| What is the average age of diagnosis of RCC? | Typical age at diagnosis of RCC is between 50 and 70 years old. |
| Does RCC have a gender predilection? | Yes, males are more commonly affected at a ratio of approximately 2:1. |
| What are the risk factors for RCC? | Smoking, obesity, dialysis, and cyclophosphamide use. Sickle cell disease or sickle cell trait is specifically a risk factor for medullary type RCC. |

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| Is RCC associated with any syndromes? | von Hippel-Lindau (VHL) |
| | Autosomal dominant; VHL gene on chromosome 3 |
| | Clear cell RCC, often multiple |
| | Tuberous sclerosis |
| | Sporadic more often than inherited (AD); TSC1 gene on chromosome 9 or TSC2 on chromosome 16 |
| | Multiple angiomyolipomas (rarely clear cell RCC) |
| | Hereditary papillary renal cell cancer syndrome |
| | Autosomal dominant; c-MET gene on chromosome 7 |
| | Multiple papillary RCCs |
| | Sickle cell trait |
| | Renal medullary RCC with very poor prognosis |
| What is the 5-year survival of RCC? | In the absence of metastasis, the 5-year survival is 65–90%. With metastasis, however, the 5-year survival is considerably lower. |

## Indications/Contraindications

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| What are some treatment options interventional radiology can offer for treatment of renal malignancies? | Thermal ablation techniques and renal artery embolization with a wide variety of embolic agents |

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| What are some alternative invasive treatment options for renal malignancies? | Radical nephrectomy and nephron-sparing surgery (NSS) either open or laparoscopic. These options are more ideal for larger, more centrally located RCCs. NSS is preferred over radical nephrectomy for localized RCC. |
| Is there a size threshold for renal tumor thermal ablation? | Yes, renal tumors <4 cm in size typically respond better to thermal ablation. In fact, best results have been reported for tumors <3 cm in size and exophytic in location. |
| What are some indications for tumor ablation treatment of renal malignancies? | Poor surgical candidates, advanced age, solitary kidney, familial syndromes, and multiple comorbid conditions |
| What are the absolute contraindications to thermal ablation? | Uncorrectable coagulopathy with INR >1.5 and platelets <50,000 per microliter |
| What are some relative contraindications for tumor ablation? | Anteromedially/centrally located tumors with no safe route, hip prosthesis, and pacemaker/defibrillator. Large tumor size and inability to separate tumor from nearby vital structures, such as the bowel or ureter, should also be considered. |
| When can renal artery embolization be considered for treatment? | Prior to nephrectomy, for palliation, in preparation for ablation, and for the treatment of AMLs (>4 cm). Indications for palliation in the setting of advanced stage RCC include hematuria, flank pain, and control of paraneoplastic syndromes. |
| What are some contraindications to renal artery embolization? | Although there is no absolute contraindication, relative contraindications include contrast allergy, renal insufficiency, pregnancy, infection, and solitary kidney. |

## Relevant Anatomy

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| What is the basic renal anatomy? | The kidney has an outer cortex and inner medulla. The renal hilum located medially is where the renal vessels, nerves, and ureter pass. The kidneys, renal vessels, proximal collecting systems, adrenal glands, and some fat are located within the perirenal space (a retroperitoneal space), which is bound by perirenal fascia. The two other retroperitoneal spaces are the anterior and posterior pararenal spaces. |
| What are some anatomic structures to keep in mind when performing an ablation? | Vascular pedicle and any neighboring bowel and ureter. Also, it is best to avoid traversing through the lung pleura, as this can lead to a pneumothorax. |
| What are common anatomic variants that may be encountered during renal artery embolization? | Variants include accessory renal arteries and early division of the renal arteries. Being aware of these will help ensure as complete as possible of an embolization and procedure success. |
| Are there any other special considerations and/or techniques one can use when performing tumor ablation for RCC? | Hydrodissection is useful to separate the structures when there is not enough margin in between the ureter/bowel and the tumor. |
| | As mentioned above, pre-ablation embolization may reduce the risk of hemorrhage and has the benefit of less heat sink. |
| What else can be done to protect the ureter during thermal ablation? | A retrograde ureteral stent can be placed with infusion of fluid through the collecting system. |

## Relevant Materials

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| What are the different kinds of ablation techniques currently available? | Radiofrequency ablation (RFA), microwave, laser, and cryoablation. A newer procedure called irreversible electroporation (IRE) uses electric currents to increase permeability of the cell membranes. This disrupts cellular hemostasis and induces cell death via apoptosis or other internally induced necrotic pathways. |
| What different arrays are available for thermal ablation? | Both linear and multi-tined or umbrella-shaped array devices may be used depending on the shape and size of the tumor. Straight/linear electrodes may require multiple insertions. |
| What are some common embolization materials that are used? | Coils, gelfoam, polyvinyl alcohol (PVA), and Embospheres. Chemoembolization with drug-eluting embolic (DEE) agent saturated with doxorubicin has also been shown to help in palliation of RCC. There may also be potential for use of radioembolization with Yttrium-90 (Y-90) resin microspheres. |
| How does RFA work? | Briefly, the RF electrode itself is not the source of heat. Rather, the RF electrode generates an alternating electromagnetic field which agitates local molecules, resulting in the production of heat. The high temperatures results in coagulative necrosis of adjacent tissue. |
| How does microwave ablation (MWA) differ from RFA? | MWA uses an oscillating microwave electromagnetic field to increase kinetic energy and produce heat. MWA produces heat faster, has a more predictable ablation zone, and is not as affected by heat sink. |

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| How does cryoablation work? | When compressed gas, typically argon, is forced through the narrow opening of a cryoprobe, the rapid expansion of the gas results in a decrease in the temperature of the gas (Joule-Thomson effect). Cryoablation results in cell death by direct (cold-induced cellular injury) and indirect (changes to the cellular microenvironment and impairment of tissue viability) effects. |

## General Step by Step

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| What is the ideal patient positioning for ablation? | Prone in most cases and supine if the target is a transplanted kidney. Consider angling of the gantry in the prone position to aid in determining ideal needle trajectory. Oblique supine positioning can be used for laterally located lesions and also to displace the bowel medially. Ipsilateral decubitus positioning is useful for lower pole masses and aids in displacing the lung, as well as reducing target (ipsilateral) kidney motility. |
| What are some pre-procedure steps that should be taken? | Consultation including history, pre-procedure imaging, possible pre-procedure biopsy, overnight fast, and prophylactic antibiotics. A biopsy can also be performed at the same time as the ablation if necessary. |
| How is hydrodissection performed? | After achieving local anesthesia, a small needle can be introduced between the tumor and adjacent vital structure. Following this, saline can be injected and infused continuously during the procedure to help separate the tumor from the adjacent vital structure. |

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| How is pyeloperfusion performed? | A retrogradely placed ureteral stent is connected to a bag of a slow drip infusion of 1–2 drops/second. |
| What is the ablation technique utilized for cryoablation? | After advancing the ablation probe into the mass under imaging guidance, cryoablation can be performed with freeze-thaw cycles, such as a 10-minute freeze cycle followed by an 8-minute thaw cycle, followed by an additional freeze cycle. Temperatures < −40 °C are necessary to ensure tumoral cell death. |
| What is the ablation technique for RFA and MWA? | After advancing the ablation probe into the mass under imaging guidance, the mass is ablated for approximately 10 minutes for RFA and a few minutes for MWA. |
| Why is it also important to ablate the entry tract during tumor ablation? | This limits the possibility of a calyceal-cutaneous fistula and tumor seeding. Ablation should be stopped within 1 cm of the skin surface to prevent skin burns. Tract ablation is performed with heat-based ablation. |
| What must be done following ablation? | Post-ablation multiphase CT scan must be performed to demonstrate lack of vascular or collecting system injury. |
| How can the renal artery be selected for renal artery embolization? | After acquiring arterial access, 5-Fr selective catheters, such as a Sos, Cobra, or Simmons catheters, can be used to gain access into the renal artery. For small tumors, selective catheterization with microcatheters can also be achieved. Accurate selection reduces the chance of nontarget embolization and minimizes non-tumoral nephron death. |
| What embolic material should be used for renal artery embolization? | The choice of embolic material depends on the operator's experience and preference. Post-embolization angiography must be performed to demonstrate degree of desired vessel occlusion. |

## Complications

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| What are some side effects of radical nephrectomy? | Nephrectomy can increase the risk of chronic kidney disease, particularly if the patient is already diabetic. It also has a longer recovery period and is associated with increased morbidity and mortality compared to the other less invasive techniques. Complications include infection, bleeding, and even death. |
| What are some potential adverse effects of tumor ablation? | Hemorrhage, infection, ureteric stricture, bowel injury, nerve injury, adrenal crisis (consider premedication with alpha- and beta-blockers for a week), and pneumothorax |
| What are potential adverse effects of renal artery embolization? | Post-embolization syndrome consisting of fatigue, pain, fever, nausea, and vomiting. Other less likely complications include infection and nontarget embolization. |
| What are the benefits of performing renal artery embolization prior to nephrectomy? | Decreased perioperative bleeding, creation of a tissue plane which can ease in dissection of the kidney, and reduction in tumor bulk and possibly reduction in vascular thrombosis |
| What can be done to minimize the effects of post-embolization syndrome (PES) after renal artery embolization? | PES can be controlled symptomatically with pre- and post-medication, which includes steroids, pain control, antiemetics, and hydration. |

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| | If embolization was performed for nephrectomy planning, performing the nephrectomy within 48 hours of the renal artery embolization can reduce the effects of post-embolization syndrome. If nephrectomy is performed >72 hours post-embolization, the surgery can potentially become technically difficult related to collateral vessel formation. |

## Landmark Research

Clark W, Aslan P, Patel M, Vass J, Cade D, de Silva S, et al. The RESIRT study: feasibility and dosimetry considerations of selective internal radiation therapy (SIRT) using yttrium-90 (Y-90) resin microspheres in patients with primary renal cell carcinoma (RCC). J Vasc Interv Radiol. 2017;28(2 Suppl):S164.

- SIRT with Y-90 microspheres was technically feasible in patients with RCC. Tumors should be treated to imminent stasis.

Hui GC, Tuncali K, Tatli S, Morrison PR, Silverman SG. Comparison of percutaneous and surgical approaches to renal tumor ablation: metaanalysis of effectiveness and complication rates. J Vasc Interv Radiol 2008; 19:1311–1320.

- A percutaneous approach was found to be safer and just as effective in treating RCC compared to an open or laparoscopic, although multiple treatments may be needed.

Jasinski M, Siekiera J, Chlosta P, et al. Radiofrequency ablation of small renal masses as an alternative to nephron-sparing surgery: preliminary results. Videosurgery Miniinv. 2011;6:242–5.

- RFA can be safely used in treating T1a tumors as an alternative to partial nephrectomy. Careful follow-up is needed to look for tumor recurrence.

Karalli A, Ghaffarpour R, Axelsson R, Lundell L, Bozoki B, Brismar T, et al. Transarterial chemoembolization of renal cell carcinoma: a prospective controlled trial. J Vasc Interv Radiol. 2017;28(12):1664–72.

- Drug-eluting embolization (DEE) is a safe way to treat localized RCC and has a superior cytoreductive effect compared to transarterial embolization (TAE).

Kunkle DA, Uzzo RG. Cryoablation or radiofrequency ablation of the small renal mass: a meta-analysis. Cancer 2008;113: 2671–1280.

- Data suggested that cryoablation may require fewer re-treatments with improved local control and decreased risk of metastatic progression compared to RFA.

Wagstaff P, Ingels A, Zondervan P, et al. Thermal ablation in renal cell carcinoma management: a comprehensive review. Curr Opin Urol. 2014;24:474–82.

- Thermal ablation is a safe way to treat small renal masses; however, there is a small risk of residual disease.

Yin X, Cui L, Li F, et al. Radiofrequency ablation versus partial nephrectomy in treating small renal tumors: a systematic review and meta-analysis. Medicine (Baltimore) 2015;94:e2255.

- RFA has a similar oncologic benefit compared to partial nephrectomy with similar complications rates in treatment of small renal tumors. There is a lower decline in eGFR and a shorter length of stay (LOS) with RFA.

Zielinski H, Szmigielski S, Petrovich Z. Comparison of preoperative embolization followed by radical nephrectomy with radical nephrectomy alone for renal cell carcinoma. Am J Clin Oncol. 2000;23(1):6–12.

- Preoperative renal artery embolization (PRAE) is a safe technique in management of large and advanced RCC. There was decreased median blood loss in the PRAE group compared to the no-PRAE group (250 mL versus 400 mL).

## Common Questions

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| What is the heat sink effect? | Perfusion-mediated cooling by adjacent vessels which limit the size of the ablation zone. This is more of a technical challenge in RFA when compared to microwave ablation. The heat sink effect does not exist in IRE technique. |
| What is the typical follow-up after ablation? | A follow-up CT/MR with contrast can be performed in 1–3 months post-ablation and then annually. There may be some post-procedural enhancement related to hyperemia; however, an increase in the degree of enhancement as well as any asymmetric and/or nodular enhancement involving the margins of the ablation zone on subsequent scans would be suspicious for tumor recurrence/progression. |
| What is the ideal ablation margin? | A 0.5–1-cm margin is ideal. If the margin between the ablation zone and a vital neighboring structure is <1 cm, hydrodissection or pneumodissection can be used. |
| How does tumor ablation compare to the gold standard of radical or partial nephrectomy? | The 5-year recurrence-free survival rate of partial nephrectomy has been reported to be greater than 97% and that of thermal ablation to range from 87% to 97%. |
| How does the cost of thermal ablation compare to nephrectomy? | Early 6-month cost comparisons show thermal ablation to be cheaper than nephrectomy. As outcomes become comparable with time, cost comparison may begin to play a larger factor in decision-making. |
| How do cryoablation and RFA or MWA compare in performance? | Results comparing cryoablation and RFA or MWA do not vary greatly, and larger studies and trials are necessary to detect differences between the two. Therefore, the choice between them depends mostly on operator experience and preference. There is a higher bleeding risk with cryoablation compared to RFA (4.8% versus 1.2%). |

## Further Reading

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# Chapter 36
# Breast Oncology

**Monica J. Uceda and Shaji Khan**

*Evaluating Patients*

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| What are the recommendations for breast cancer screening in women? | Recommendations differ between the United States Preventive Services Task Force (USPSTF) and the American Cancer Society (ACS);<br>USPSTF<br>Age 40–49: Decision to screen should be an individual one (Grade C).<br>Age 50–74: Screen every 2 years (Grade B).<br>Age ≥75: No recommendation (insufficient evidence). |

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| | ACS<br>Women 40–44 can begin annual screening mammography.<br>Women 45–54 should undergo annual screening mammography.<br>Women ≥55 can transition to every-other-year screening OR continue annual screening mammography.<br>Women should continue screening mammography as long as their overall health is good and they have a life expectancy of 10 years or longer.<br>Women at any age should not rely on breast examination for breast cancer screening. |
| What are the most suspicious mammographic findings? | Irregular mass with obscured, indistinct or spiculated margins, pleomorphic or fine linear branching calcifications, developing asymmetry, architectural distortion, skin thickening, nipple retraction and lymphadenopathy. |
| What are the most suspicious sonographic findings? | Round lesion, non-parallel and/or irregular margins (angular), posterior shadowing, hypoechoic, not circumscribed, internal vascularity and lymphadenopathy. |
| What benign lesion can appear suspicious on ultrasound? | A scar can appear non-circumscribed and demonstrate posterior acoustic shadowing, as well as spiculated margins. |
| What is the work-up of a palpable mass? | Diagnostic mammogram and breast ultrasound. |
| What are ultrasound features of fibroadenoma? | Parallel, oval, hypoechoic lesion with circumscribed margins and no posterior features. |

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| | BIRADS-3; 6-month follow-up is necessary to show stability.<br>Reasons to biopsy:<br>Interval growth<br>Patient anxiety<br>High likelihood of losing the patient during follow-up |
| What is the value of breast MRI? | Screening for high-risk patients and evaluating cancer extension. |
| What is a "second look" ultrasound? | Targeted ultrasound of a corresponding area of abnormal enhancement on MRI. |
| What additional imaging modalities can be used for further evaluation? | Breast-specific gamma imaging (BSGI) and positron emission mammography (PEM). |

## High Yield History

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| What is the incidence of breast cancer in the United States? | 126.5 per 100,000 women and 1.1 per 100,000. It is the most common cancer in women independent of race or ethnicity. |
| What is the mortality of breast cancer in the United States? | 20.3 per 100,000 women and 0.3 per 100,000 men. The mortality rate has recently decreased by 39% due to improved treatment and early detection. |
| What is the average age at diagnosis? | 62 years old, with most cancer deaths in women ≥50. |

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| What are the risk factors? | Older age, personal history, family history, BRCA1/BRCA2 genes, radiation to chest <30 years old, white race, obesity, nulliparous, early menarche, late menopause, hormone replacement therapy, smoking and dense breasts. |
| What are symptoms of breast cancer? | Palpable mass, lymphadenopathy, skin thickening and nipple retraction. In the case of inflammatory breast cancer: peau d'orange, redness and swelling. |

## Indications/Contraindications

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| What are the methods available for image-guided breast biopsies? | Stereotactic interventions, US-guided interventions, MR-guided breast biopsy, and the new vacuum-assisted nuclear medicine breast biopsy techniques. |
| What are common contraindications for the image-guided breast biopsy? | Bleeding disorders, uncooperative patient, morbid obesity. |
| What are the indications for the stereotactic biopsy? | Newly diagnosed suspicious microcalcifications seen on mammography or digital tomosynthesis classified as BI-RADS 4 or 5<br><br>Suspicious lesions seen best in mammogram or without an ultrasound correlate |
| What are the indications for the US-guided breast biopsy? | Any lesion definitely identified as suspicious by ultrasound. |
| What are the advantages of the US-guided breast biopsy? | Real-time visualization, shorter procedural time, patient's comfort, and no radiation. |

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| What are the indications for the MR-guided breast biopsy? | Suspicious lesions only visualized with MRI. |
| What are the techniques available for breast cancer ablation? | Radiofrequency ablation (RFA) and cryoablation. |
| Which lesions could be best treated with ablation? | Breast cancer single lesions ≤1.5 cm and histologically different from invasive lobular carcinomas. |

## Relevant Anatomy

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| What are the three zones of the breast in mammography? |

| | **Boundaries** | **Content** |
|---|---|---|
| Premammary zone | Skin to anterior mammary fascia | Subcutaneous fat, blood vessels, ligaments of Cooper. May contain ectopic ducts and TDLU |
| Mammary zone | Anterior to posterior mammary fascias | Majority of ducts/TDLU, stromal fat, and stromal connective tissue |
| Retromammary zone | Posterior mammary fascia to chest wall | Fat and posterior suspensory ligaments |

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| What are the layers identified in breast ultrasound? | Skin, subcutaneous tissue, glandular tissue, pectoralis major, and chest wall. |

## Relevant Materials

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| What is the set-up for stereotactic breast biopsy? | Dedicated table or digital mammography unit attachment and a special chair for positioning. |
| What size biopsy needles are utilized? | 11-, 9-, 8-, or 7-gauge. |
| What are the benefits of vacuum-assisted devices? | Actively drawing tissue into the biopsy chamber allows for larger and multiple tissue samples, and increases diagnostic accuracy. |
| How do you select the appropriate device/ technique for US-guided breast biopsies? | Fine needle aspiration (FNA) for cystic or mixed lesions and core needle biopsies (CNB) for solid lesions. |
| What are the advantages or disadvantages of FNA? | Advantages: low cost and likelihood of hematoma.<br><br>Disadvantages: operator-dependent and inability to differentiate between DCIS and IDC. |
| What device options exist for CNB? | Automated spring-loaded or vacuum-assisted devices. |
| What are the advantages or disadvantages of CNB? | Advantages: higher likelihood of negative margins during surgery and ability to perform oncologic markers with the sample.<br><br>Disadvantages: higher cost and need for multiple re-insertions with automated devices. |
| When is a vacuum-assisted device preferred for CNB? | Suspicion of intraductal papillomas. |
| What are the available MRI-guided biopsy platforms? | Grid system and pillar-and-post system. |

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| How is the needle placed in a grid system? | Orthogonally to the compression plate. |
| How is the needle placed in a pillar-and-post system? | Accommodates needle angulation up to 30 degrees. |
| What are the components of the introducer set in the MRI-guided biopsy? | Needle guide, coaxial introducer sheath, sharp nonferrous inner stylet, and plastic localizing obturator. |
| What is the mechanism of action of RFA? | High-frequency alternating currents cause thermal coagulation and protein denaturation of tissues. |
| What is the advantage of ablation compared to surgery? | Minimally invasive procedures and improved cosmesis. |
| What is the mechanism of the action of cryoablation? | Nitrogen or argon gas causes a local freezing reaction ("ice ball") which induces direct cell injury and death via vasoconstriction. |
| What are the advantages of cryoablation? | Can be performed under mild sedation and local anesthesia. |

## General Step by Step

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| How is the patient positioned for a stereotactic breast biopsy? | Prone with the breast positioned dependently through an aperture in the table. |
| What types of images are taken before stereotactic procedures? | +15 and − 15 degree images. |
| What is the best approach during a stereotactic procedure? | 1. Select the projection in which the lesion is best visualized. |

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| | 2. After initial imaging, the computer generates $x$, $y$, and $z$ coordinates. |
| | 3. Place the lesion in the center of the biopsy chamber of the probe. |
| What if the lesion is too superficial? | Advance the probe to a position where the entire biopsy chamber is just beyond the skin. |
| What if the lesion is too deep? | Reposition the patient. |
| Why is it important to obtain a post-procedure mammogram? | To confirm the lesion has been biopsied and identify the biopsy clip. |
| What size needle is used for FNA? | 22- to 25-gauge needles. |
| What is the best approach for FNA? | Several passes through different areas of the lesion. |
| What size needle is used for CNB? | 12- to 14-gauge. |
| What is the best approach for CNB? | 1. Advance device 1–3 cm proximal to the edge of the lesion. |
| | 2. Fire into the lesion. |
| | 3. Turn the needle and remove. |
| | 4. 3–5 passes are needed with automated spring-loaded devices. |
| | 5. Place a biopsy clip. |
| What is the best approach to perform an MRI-guided breast biopsy? | 1. Place the patient prone in an MRI biopsy coil. |
| | 2. Scout images and contrast administration. |

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| | 3. The computer generates $x$, $y$, and $z$ coordinates.<br>4. Coaxial sheath is inserted through the stylet.<br>5. Stylet is removed and obturator is placed.<br>6. Remove obturator and VAB is advanced to obtain samples.<br>7. Place titanium clip. |
| What is the use of a post-biopsy scan in the MRI-guided breast biopsy? | Document adequate clip placement, identify lesion removal, or decrease in size. |
| If the lesion is not identified in MRI, what are the next steps? | Decrease breast compression, second dose of contrast, short-term interval follow-up MRI. |
| How is RFA performed? | Probes are placed under US guidance and ablation is performed under real-time sonographic visualization. The procedure is complete when the desired temperature is obtained. |
| How is cryoablation performed? | Cryoprobes are placed under US guidance and ablation is performed under real-time sonographic visualization. The "ice ball" allows for homogenous tissue destruction. Helium or passive thawing can be applied after the freezing portion of the procedure. |
| What is the most important step on cryoablation? | Creating an "ice ball" larger than the tumor in order to ensure negative margins. |

## Complications

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| What are the most common complications of image-guided breast biopsies? | Bleeding, and less frequently infection and persistent pain. |
| How can we avoid a pneumothorax during the US-guided breast biopsy? | Placement of the needle parallel to the chest wall. |
| What are the complications of breast cancer ablation? | Skin burns and mass formation at the probe site. |

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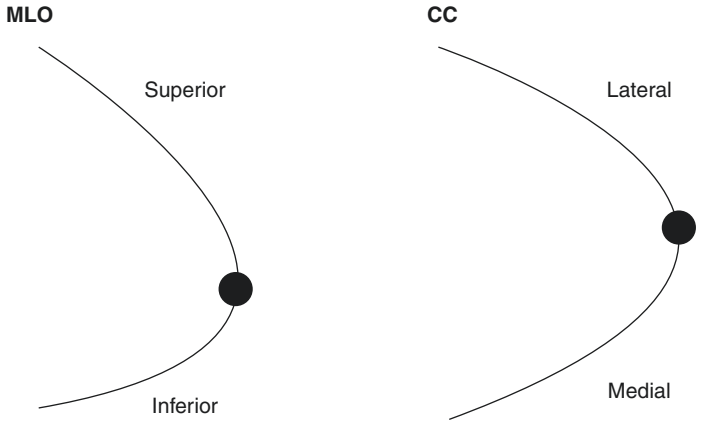
## Common Questions

What is the BI-RADS classification?

| **BI-RADS** | | **Annual mammogram** |
|---|---|---|
| **1** | **Normal** | |
| BI-RADS 2 | Benign | Annual mammogram |
| BI-RADS 3 | Probably benign | Short-term 6 months' follow-up |
| BI-RADS 4 | Suspicious | Tissue sampling |
| BI-RADS 5 | Highly suspicious | Tissue sampling |
| BI-RADS 6 | Known biopsy-proven malignancy | Treat accordingly |

How can we identify the location of breast lesions in mammography?

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| Who is a high-risk patient? | BRCA positive (including untested first-degree relatives), history of chest radiation, risk model ≥ 20%. |
| What are the screening recommendations for high-risk patients? | Mammography (preferably Tomosynthesis) and MRI. |
| What is the best time of the menstrual cycle to perform a breast MRI? | 7–14 days. |
| What is a "pancake breast"? | Breast that compresses < 2 cm. This is a specific contraindication for stereotactic biopsy. |
| What is the best method for follow-up after breast cancer ablation? | MRI breast with contrast. |
| What devices are available for RFA in the breast? | Covidien Cool Tip, Integra Elektrotom HiTT, Boston Scientific LeVeen, and Angiodynamics Starburst. |

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| What is the relevant data supporting the use of RFA in early-stage breast cancer? | In 2013, Kreb et al. analyzed the results of cryoablation in 20 lesions ≤ 1.5 cm. Complete cell death of the target was reported in 85% of lesions. In 2017, a retrospective study in Japan evaluated 386 patients and obtained ipsilateral breast tumor recurrence free (IBTR) rates of 97%, 94%, and 87% for tumors ≤ 1 cm, 1.1–2.0 cm and > 2 cm, respectively. |
| How does RFA compare to lumpectomy in early-stage breast cancer? | A very recent prospective randomized clinical trial with 40 subjects demonstrated RFA is effective for local tumor control and that tumor-free margins were obtained more often with RFA than with lumpectomy. |
| How many freeze/thaw cycles are recommended when performing cryoablation? | Two freeze/thaw cycles are recommended for complete treatment. |
| What devices are available for cryoablation in the breast? | Sanarus Visca-2 system and Ice-Cure Medical IceSense-3 system. |
| What is the relevant data supporting the use of cryoablation in early-stage breast cancer? | A phase II clinical trial in 2017 evaluated 86 patients and 87 stage I breast cancer lesions. When multifocal disease outside of the targeted cryoablation zone was not defined as an ablation failure, 92% of the treated cancers had a successful cryoablation. Littrup et al. analyzed 22 lesions in 11 patients and there were no local recurrences in 18 months follow-up after cryoablation. |

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| How does cryoablation compare to lumpectomy in early-stage breast cancer? | A multicenter non-randomized clinical trial is being conducted to evaluate the potential use of cryoablation instead of resection in small breast tumors (FROST trial). The accrual goal is 220 patients and the lesions included are ≤1.5 cm without nodal extension. The primary endpoint is complete tumor ablation and secondary endpoints include IBTR rate, breast cosmesis, and adverse events. |

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# Part V
# Hepatobiliary

# Chapter 37
# Percutaneous Biliary Interventions

**Jacob J. Bundy, Jeffrey Forris Beecham Chick, and Ravi N. Srinivasa**

## Evaluating the Patient

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| What are the common biliary interventions which interventional radiology may offer patients? | Percutaneous transhepatic cholangiography (PTC) and biliary drainage (PTBD), percutaneous biliary stent placement, and percutaneous cholecystostomy (PC). |

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| What are the common causes of benign biliary obstruction? | The flow of bile may be disrupted by either benign or malignant causes. Benign biliary obstructions are commonly caused by migrated cholelithiasis (gallstones) into the common bile duct (choledocholithiasis), benign stricture formation following invasive procedures, and strictures related to chronic inflammation secondary to chronic pancreatitis or primary sclerosing cholangitis. |
| What are the common causes of malignant biliary obstruction? | Malignant biliary obstructions are commonly caused by pancreatic adenocarcinoma, cholangiocarcinoma, lymphoma, and metastases from another primary neoplasm. |
| What are the physical signs and symptoms associated with biliary tree obstruction? | Jaundice, bilirubinuria (darkening of the urine), acholic stool, pruritus, anorexia, nausea, and fatigue. |
| What are the laboratory studies which are indicative of a biliary obstruction? | The typical cholestatic pattern observed during a biliary obstruction include elevation in the serum bilirubin (conjugated hyperbilirubinemia), elevation of the serum alkaline phosphatase out of proportion to the serum aminotransferases, and elevated gamma-glutamyl transpeptidase. |

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| What imaging studies are useful in the evaluation of suspected biliary obstruction? | Transabdominal ultrasonography (US) is a common imaging modality used in the early evaluation; however, overlying bowel gas may limit extrahepatic bile duct evaluation. Magnetic resonance cholangiopancreatography (MRCP) and computed tomographic cholangiography offer cross-sectional anatomic models to evaluate the level of obstruction. |
| What is the role of endoscopic retrograde cholangiopancreatography (ERCP) in the evaluation of biliary obstruction? | ERCP is the preferred method of biliary intervention as it allows for simultaneous diagnosis and treatment of biliary obstructions. Altered anatomy (Roux-en-Y gastric bypass and hepaticojejunostomy) and high bile tree obstructions (obstructions proximal to or involving the confluence of the left and right hepatic ducts), however, are generally more amenable to percutaneous interventions. |

## High Yield History

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| What is Charcot's triad? Reynold's pentad? | Charcot's triad refers to the three classical features associated with cholangitis; right upper quadrant pain, fever, and jaundice. Reynold's pentad adds mental status changes and sepsis or hypotension to the clinical findings suggestive of cholangitis. |

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| What is the Bismuth-Corlette classification? | It is a classification system used in patients with hilar cholangiocarcinoma to describe the anatomic location of high bile ducts obstructions. |
| What surgical procedure is most commonly associated with biliary leaks? | Laparoscopic cholecystectomy. |
| When seen on imaging, what is the significance of atrophy of affected liver segments? | Parenchymal atrophy is caused by chronic biliary or portal venous obstruction. Drainage of these segments is less likely to provide a benefit to recovered liver function. |
| What are the findings suggestive of choledocholithiasis on transabdominal US? | A dilated CBD > 6 mm is the generally accepted cutoff used to classify the duct as dilated.<br><br>The CBD diameter, however, increases with age, so older adults may have a duct > 6 mm in the absence of disease.<br><br>Other signs of hepatobiliary stone disease include gallbladder wall thickening, cholelithiasis, and pneumobilia. |
| What is Mirizzi syndrome and how does it present? | It is defined as the obstruction of the common hepatic duct secondary to extrinsic compression from a stone located within the cystic duct or Hartmann's pouch of the gallbladder. It also presents with jaundice, fever, and right upper quadrant pain; however, particular attention must be directed toward the detection of potential cholecystobiliary fistulas. |

## Indications/Contraindications

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| What are PTC and PTBD? | PTC is a minimally invasive diagnostic procedure that involves the placement of a small-gauge needle into peripheral biliary tract under image guidance, followed by the injection of contrast to delineate biliary anatomy and detect biliary obstructions. Following cholangiography, a tube or stent may be placed for external or internal drainage (PTBD). |
| What is PC? | Cholecystostomy is a therapeutic procedure that involves the image-guided placement of a tube for external drainage of gallbladder contents. |
| What are the indications for percutaneous biliary interventions according to the Society of Interventional Radiology (2010) guidelines? | PTC: Define the level of obstruction in patients with dilated bile ducts, evaluate for bile duct stones, determine the etiology of cholangitis, evaluate and determine the site of bile duct leak, and determine the etiology of transplanted hepatic graft dysfunction.<br><br>PTBD: Provide biliary drainage, decompress obstructed biliary tree, divert bile and place stents in bile duct defects, provide portal of access to dilate biliary strictures, remove bile duct stones, stent malignant lesions, brachytherapy, endoluminal tissue sample, and foreign body retrieval.<br><br>PC: Gallbladder access, management of cholecystitis, portal for removal of stones, biliary tract access, decompress obstructed biliary tract, divert bile from bile duct defect, and provide portal of access for the therapeutic processes listed under PTBD. |

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| What are the contraindications to percutaneous biliary interventions? | The primary absolute contraindication to these interventions is uncorrectable coagulopathy. The Society of Interventional Radiology generally recommends correcting the INR to ≤ 1.5 and transfusing platelets to a level of ≥ 50,000/μL. Relative contraindications include attempting access into non-dilated ductal system or a non-distended gallbladder, allergy to iodinated contrast agents, and ascites. |
| When should the placement of internal biliary stents be avoided? | Stent placement should not be performed when there is infected bile or active hemobilia. |

## Relevant Anatomy

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| What is the route of biliary drainage? | The confluence of the right and left hepatic ducts (the primary biliary confluence) forms the common hepatic duct. The common hepatic duct joins the cystic duct to form the common bile duct. The common bile duct joins the pancreatic duct close to the ampulla of Vater, which drains into the descending part of the duodenum. |
| According to the Couinaud classification of liver segments, which segments compose the left hepatic lobe? Right hepatic lobe? | The left lobe is composed of by segment 1 (caudate lobe), segment 2 (superior and posterior), segment 3 (anterior and inferior), and segment 4. The right hepatic lobe is divided into the anterior (segments 5 and 8) and posterior (segments 6 and 7) sectors by the right hepatic vein. |

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| What is the ideal location for initial biliary tree catheter cannulation? | Third-order or higher bile ducts are preferable for initial catheter placement so as to avoid injury to larger central vascular structures and to ensure adequate working room proximal to the site of duct injury or occlusion. |
| Where are the ducts of Luschka located and what is their importance? | The ducts of Luschka (subvesicular ducts) are small, accessory biliary ducts 1–2 mm in diameter that originate in the right hepatic lobe and course along the center or periphery of the gallbladder fossa. Following the cystic duct, the ducts of Luschka are the most common cause of post-cholecystectomy bile leaks. |
| Where does cholangiocarcinoma most commonly develop? | Within the extrahepatic bile ducts. When the tumor involves the hepatic bifurcation (hilar cholangiocarcinoma), it is called a Klatskin tumor. |
| What are the classifications of obstructions used in Bismuth-Corlette system? | Type I: Tumors below the confluence of the left and right hepatic ducts. |
| | Type II: Tumors reach the confluence, but do not involve the right and left hepatic ducts. |
| | Type III: Tumors occluding the common hepatic ducts and either the right (IIIa) or left (IIIb) hepatic duct. |
| | Type IV: Tumors that are metacentric or involve the confluence and both the right and left hepatic duct. |

## Relevant Materials

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| Is antibiotic prophylaxis recommended by the Society of Interventional Radiology (2010) prior to biliary interventions? | Antibiotic prophylaxis is recommended; however, no consensus has been reached on the first-line agent. Common antibiotics choices include: ceftriaxone, ampicillin/sulbactam, cefotetan plus mezlocillin, and vancomycin or clindamycin plus aminoglycoside if penicillin-allergic. |
| What is an internal-external biliary drain? | It is a drainage catheter with a locking loop located in the duodenum and multiple side holes. This form of drain allows for either external drainage to a bag or the exteriorized portion of the catheter may be capped to force internal drainage of bile. |
| When would an external biliary drain be placed? | This form of drain may be placed when the biliary obstruction cannot be crossed or in septic patients in whom minimal manipulation is desired. |
| When would stents be placed within the biliary system? | Biliary stents are generally placed for malignant biliary obstruction when duct patency may be compromised for a prolonged period. Once stent patency is confirmed, drains may be removed leaving the patient without external devices and improved quality of life. |

## General Step by Step

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| What is the common anatomic landmark to select for right-sided biliary drainage? | A low intercostal approach near the mid-axillary line is preferred to avoid transgression of the lung pleura. Generally, if the needle enters at or below the superior margin of the 11th rib, this complication may be avoided. |

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| What is the common approach for access of the left biliary system? | Sub-xiphoid US-guided puncture using a 21-gauge needle or fluoroscopic-guidance with the needle directed toward the liver and 30–45 degrees posteriorly and superiorly. |
| What signs indicate the puncture of the biliary system? | As the needle is slowly withdrawn, contrast is injected into the liver parenchyma. When contrast is injected into the hepatic arteries, a pulsatile flow directed toward the liver periphery is observed. Hepatic veins and the portal venous system are non-pulsatile with flow into right-angled tributaries. Bile ducts are recognized by slow flow directed centrally. |
| After gaining access into the biliary system, how is the biliary system decompressed? | A 0.018-inch guidewire is inserted into the needle within the biliary system and then a coaxial transition set is advanced over the guidewire. This will consist of a 5- or 6-F sheath, which will allow bile to flow out of the sheath sidearm. This bile may then be sent for culture. |
| How are drainage catheters placed within the biliary system? | Once obstructions have been crossed using a 0.035-inch straight, floppy tip wire and the wire has been passed into the duodenum, the original wire is exchanged for a 0.035-inch exchange guidewire. Over this wire, the tract may be sequentially dilated to allow placement of an 8- to 12-F drainage catheter. |
| How are ductal strictures dilated? | High-pressure balloons, which are oversized by approximately 20% of the estimated duct diameter, are used to dilate ductal strictures. |

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| What are the general steps involved with PC? | Under US guidance, the gallbladder is accessed with a needle and placement within the gallbladder is confirmed with fluoroscopic contrast-injection. A guidewire is then advanced through the needle and coiled within the gallbladder. Following the dilation of the tract, an 8-to-10-F locking pigtail catheter is then advanced and formed within the gallbladder to allow for decompression. |

## Complications

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| What are the most common complications following PTC? | Sepsis, bile leak, hemorrhage, and pneumothorax occur at a rate of 2% overall. |
| What is the most common cause of sepsis during PTC? | Sepsis generally results from over-injection of contrast into infected biliary ducts. |
| What are the most common complications following PTBD? | Major complications following PTBD occur in 8% of cases with sepsis and hemorrhage as the leading complications. Other complications include abscess formation, pleural transgression, colonic perforation, bile leak, and death. |
| What is the leading cause of major hemorrhage following biliary interventions and how is it managed? | Injury to the hepatic artery by a needle or catheter may lead to extravasation or pseudoaneurysm formation. Bleeding which does not subside within 24–48 hours generally requires an arteriogram followed by intervention with embolics. |
| What complications are associated with PC? | Bile leak with associated peritonitis, bleeding, sepsis, and catheter dislodgement are documented to occur in 5% of cases. |

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| What is the ideal tract placement for PC to avoid dislodgement? | Tract placement through the liver and bare area has been suggested as a more stable tract that minimizes the impact of respiratory movement. |

## Landmark Research

Hepatic arterial injuries after percutaneous biliary interventions in the era of laparoscopic surgery and liver transplantation: experience with 930 patients.

Fidelman N, Bloom AI, Kerlan RK, LaBerge JM, Wilson MW, Ring EJ, et al. Hepatic Arterial Injuries after Percutaneous Biliary Interventions in the Era of Laparoscopic Surgery and Liver Transplantation: Experience with 930 Patients. Radiology. 2008 Jun 1;247(3):880–6.

- Retrospective review of 930 patients undergoing percutaneous biliary interventions to assess for factors associated with arterial injuries.
- The overall rate of arterial injury in the study population was 2.2% with no significant difference in the rate of arterial injury among patients with malignant biliary obstruction, those with a history of bile duct injury, and those with complications of liver transplantation.
- A 3.7-fold higher rate of AI was observed after PTBD than after PTC.

Society of Interventional Radiology Quality Improvement Guidelines for Percutaneous Transhepatic Cholangiography, Biliary Drainage, and Percutaneous Cholecystostomy

Saad WEA, Wallace MJ, Wojak JC, Kundu S, Cardella JF. Quality Improvement Guidelines for Percutaneous Transhepatic Cholangiography, Biliary Drainage, and Percutaneous Cholecystostomy. Journal of Vascular and Interventional Radiology. 2010 Jun 1;21(6):789–95.

- Outlines the definitions, indications, and complications for three commonly performed biliary interventions

- Provides procedure-related complication thresholds which should require a review to be performed to determine causes and to implement changes if the rates exceed the thresholds

Comparison of percutaneous transhepatic biliary drainage and endoscopic biliary drainage in the management of malignant biliary tract obstruction: a meta-analysis.

Zhao X, Dong J, Jiang K, Huang X, Zhang W. Comparison of percutaneous transhepatic biliary drainage and endoscopic biliary drainage in the management of malignant biliary tract obstruction: a meta-analysis. Dig Endosc. 2015 Jan;27(1):137–45.

- Meta-analysis of eight trials including 692 patients the with management of malignant biliary tract obstruction.
- This study revealed no significant difference in therapeutic success between PTBD and endoscopic biliary drainage.
- After excluding two studies that appeared to be outliers, PTBD exhibited a better therapeutic success rate and a lower incidence of cholangitis than endoscopic biliary drainage.

Comparing percutaneous primary and secondary biliary stenting for malignant biliary obstruction: A retrospective clinical analysis.

Chatzis N, Pfiffner R, Glenck M, Stolzmann P, Pfammatter T, Sharma P. Comparing percutaneous primary and secondary biliary stenting for malignant biliary obstruction: A retrospective clinical analysis. Indian J Radiol Imaging. 2013;23(1):38–45.

- Retrospective review of 62 patients undergoing percutaneous biliary stenting for obstructive jaundice.
- Secondary biliary stenting (staged procedure) patients had a higher rate of complications in general as well as a higher rate of severe complications than patients who underwent primary biliary stenting.
- By virtue of requiring shorter hospital stays, primary stenting is likely to be more cost-effective.

Percutaneous cholecystostomy: long-term outcomes in 324 patients.

Bundy J, Srinivasa RN, Gemmete JJ, Shields JJ, Chick JFB. Percutaneous Cholecystostomy: Long-Term Outcomes in 324 Patients. Cardiovasc Intervent Radiol. 2018 Jun;41(6):928–34.

- Retrospective review of 324 patients undergoing cholecystostomy tube placement.
- Technical success rate of tube placement was 100% with no major complications.
- Mean cholecystostomy tube indwelling time was 89 days; however, there are a small proportion of patients (4%) that are continually undergoing cholecystostomy tube changes with no future plans for definitive treatment.

## Common Questions

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| What is the ideal location of the drainage catheters to allow for appropriate decompression of the biliary system? | Catheters should be positioned to allow the sideholes to be both proximal and distal to the leak or obstruction. |
| How often should biliary drains be flushed? | Drains draining bloody bile should be flushed with 5–10 mL of normal saline every 6 to 8 hours. Once normal appearing bile is draining, flushing can be performed once daily. |
| How long does it take for a tract to mature? | Tracts must mature for approximately 3 weeks before the catheter may be removed; however, it may take up to 6 weeks if a transperitoneal approach was used. |

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| How often should patients under catheter exchanges? | If long-term drainage is required, catheter exchanges should occur every 1–3 months, at which time tube cholangiograms should be performed to confirm proper placement. |

## Further Reading

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Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, et al. Addendum of newer anticoagulants to the SIR consensus guideline. J Vasc Interv Radiol. 2013;24(5):641–5.

Patel N, Chick JFB, Gemmete JJ, Castle JC, Dasika N, Saad WE, et al. Interventional radiology-operated cholecystoscopy for the management of symptomatic cholelithiasis: approach, technical

success, safety, and clinical outcomes. AJR Am J Roentgenol. 2018;210(5):1164–71.

Srinivasa RN, Patel N, Hage AN, Chick JFB. Interventional radiology-operated cholecystoscopy and cholecystolithotripsy: a guide for interventionalists. J Vasc Interv Radiol. 2018;29(4):585.

Teplick SK, Flick P, Brandon JC. Transhepatic cholangiography in patients with suspected biliary disease and nondilated intrahepatic bile ducts. Gastrointest Radiol. 1991;16:193.

Venkatesan AM, Kundu S, Sacks D, Wallace MJ, Wojak JC, Rose SC, et al. Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. Written by the Standards of Practice Committee for the Society of Interventional Radiology and Endorsed by the Cardiovascular Interventional Radiological Society of Europe and Canadian Interventional Radiology Association. J Vasc Interv Radiol. 2010;21(11):1611–30.

# Chapter 38
# Transjugular Intrahepatic Portosystemic Shunt (TIPS)

**Andrew Moore**

## Evaluating the Patient

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| Which details of a cirrhotic patient's history would be most pertinent prior to the procedure? | It is important to evaluate the patient's overall functional status, baseline liver function, any baseline encephalopathy, the presence of a liver tumor, and any prior treatments to the liver. |
| Why is it important to evaluate the patient's mental status on physical exam? | TIPS can be performed under both moderate sedation and general anesthesia. Indications for general anesthesia may include patients with severe hepatic encephalopathy, who are unable to follow commands, as well as a critically ill patient in the setting of intractable bleeding. |

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| What physical exam abdominal finding may potentially interfere with the TIPS procedure? | The presence or absence of ascites. It is common to perform a large-volume paracentesis prior to the procedure for tense ascites. Additional pertinent physical exam findings include evaluation of mental status (as described above), presence of asterixis, signs of right heart failure, and stigmata of portal hypertension such as caput medusa. |
| What are the necessary laboratory values to obtain pre-procedurally? | CBC, PT, INR, serum albumin, total bilirubin, and serum creatinine. |
| In the elective setting, what are acceptable platelet/INR values? | Platelets > 50,000/$cm^3$ and INR < 1.8. Coagulopathies should be corrected prior to proceeding, if possible. |
| Why is it important to clarify possible antibiotic allergies for the TIPS procedure? | Antibiotic prophylaxis should be administered immediately prior to starting the procedure per Society of Interventional Radiology guidelines to prevent against "endotipsitis" originating from possible pathogens in the skin, biliary, and enteric flora. Skin coverage is usually provided by cefazolin while biliary and enteric flora require much wider coverage. Possible medication allergies would guide an appropriate choice; for example, vancomycin or clindamycin in those with cephalosporin allergy. In addition, allergies to contrast and lidocaine should be clarified. |
| Which risks should be discussed with and detailed for the patient during informed consent? | The patient should be aware that there is a 1% procedure-related mortality. Additionally, there is inherent risk of developing new or exacerbating pre-existing hepatic encephalopathy. |

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| What history is pertinent for the evaluation of a patient with a prior TIPS placement? Important ultrasound findings? | Any recurrent ascites in a patient with a prior TIPS should be evaluated for malfunction. Non-invasive evaluation of a TIPS is performed utilizing color Doppler ultrasound to evaluate for signs of stenosis or complete occlusion. Signs of possible stenosis include a velocity of > 190 cm/sec at a stenotic segment and/or a velocity of < 90 cm/sec in non-stenotic segments of the stent. Phasic waveforms are expected within the TIPS stent. |

## High Yield History

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| What are the most common causes of pre-sinusoidal, sinusoidal, and post-sinusoidal portal hypertension? | Pre-sinusoidal: Portal vein thrombosis and extrinsic compression of the portal vein<br><br>Sinusoidal: Cirrhosis<br><br>Post-sinusoidal: Budd-Chiari syndrome, hepatic veno-occlusive disease and right heart failure |
| For a cirrhotic patient with acute upper GI bleeding, what confirmatory exam should be performed prior to considering TIPS? | Upper endoscopy should be the first-line diagnostic exam to confirm the source of variceal bleeding and to document variceal location. Additionally, endoscopy serves as the first-line treatment for patients who present with acute upper GI hemorrhage. |
| Which pre-procedural imaging procedures can be helpful for operative planning? | Preoperative CT or MRI of the liver can be helpful for assessing patency and position of the portal veins, presence of ascites, presence and location of varices and spontaneous portosystemic shunts, size of the liver, and signs of right heart failure. Additionally, Doppler ultrasound can confirm patency of the portal system. |

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| What information specifically regarding variceal bleeding is important to obtain from the patient's history? | Prior episodes of variceal bleeding, as well as whether or not endoscopic or medical therapy has been attempted to control variceal hemorrhage. |
| Why is it important to establish and document the patient's baseline hepatic encephalopathy pre-procedurally? | If the patient's post-procedure encephalopathy is significantly worsened from baseline, a TIPS modification may be required. |
| What is the importance of the Model for End-Stage Liver Disease (MELD) score in the setting of possible TIPS placement? | MELD (calculation below) can be a predictor of patient mortality following a TIPS procedure. Additionally, it is important to establish pre-procedurally whether or not the patient is a viable transplant candidate. The most recent version of the MELD score corrects for serum sodium level and scores $\geq$18 have demonstrated 18% and 35% 1- and 3-month mortality, respectively.<br><br>MELD = 9.6 log *e* (creatinine mg/dL) + 3.8 × log *e* (bilirubin mg/dL) + 11.2 × log *e* (INR) + 6.4 |
| What is the most pertinent patient history when evaluating for hepatorenal syndrome (HRS)? | Decreased urine output in the setting of known liver failure would be suspicious for hepatorenal syndrome, especially in the setting of an acutely increased serum creatinine level. A complex phenomenon, HRS is thought to be related to decreased renal blood flow associated with changes of cirrhosis. |

## Indications/Contraindications

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| What are the principle indications for the TIPS procedure? | Variceal hemorrhage not controlled by endoscopy/medical therapy, refractory ascites, refractory hepatic hydrothorax, and Budd-Chiari syndrome. |
| Is hepatorenal syndrome an indication for TIPS? | Emerging indications for TIPS include: hepatorenal syndrome, portal hypertensive gastropathy, TIPS for first-time variceal hemorrhage, and early TIPS for ascites |
| What are the 5 absolute contraindications to TIPS? | Severe hepatic failure, sepsis, severe heart failure, pulmonary hypertension or isolated gastric varices with splenic vein occlusion. Isolated gastric varices in the presence of splenic vein occlusion is a sign of sinistral (left-sided) hypertension, which has different treatment options. |
| What are some relative contraindications to TIPS? | Severe hepatic encephalopathy, platelet count less than 50,000, INR >1.8, biliary dilatation, and portal vein cavernous transformation. |

## Relevant Anatomy

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| The TIPS procedure connects which vessels within the liver? | Hepatic vein to portal vein. |
| Specifically, which is the most common vascular connection to make for a TIPS? | Right hepatic vein (RHV) into right portal vein (RPV), which is typically easiest technically and safest due to its spatial relationship with other critical vascular structures. |
| What is the anatomic relationship between the RHV and RPV? | RHV is posterior and superior to the RPV. |

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| What is the anatomic relationship between the RPV and middle hepatic vein (MHV)? | The MHV can lie anterior to the RPV, necessitating punctures to be angled posteriorly. |
| What risk is associated with anterior puncture from the middle hepatic vein (MHV)? | Hepatic capsular perforation. |
| What is the best projection for distinguishing the RHV from the MHV? | Lateral projection can be easier than the AP projection to differentiate between the RHV and MHV. |
| What two methods are available for intraprocedural visualization of the portal veins? | Wedged hepatic venography or intravascular ultrasound. |
| Which contrast agents are useful for portal vein visualization? | Conventional contrast or CO2. |

## Relevant Materials

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| What does a standard TIPS set include? | Multiple companies produce TIPS kits, including the Ring, Rosch-Uchida and Colapinto sets. Although kits slightly vary in contents, the standard set includes:<br>40 cm 10 Fr sheath with end marker<br>51 cm curved guide catheter with metal stiffener<br>60 cm long sheathed needle |

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| Which guidewires are most commonly utilized and should be available? | 3 mm J wire, regular and stiff curved hydrophilic wires, and regular and short-tip Amplatz wires. |
| What sizes of angioplasty balloons should you have available during a TIPS? | 5–12 mm diameter by 4–8 cm in length balloon catheters. |
| What are the most common stent/stent graft diameter sizes used for TIPS procedures? | 8, 10, and 12 mm. The most commonly deployed size is 10 mm in diameter with controlled-expansion technology, allowing initial deployment to post-dilate typically to 8 mm, with the possibility of future dilatation to 10 mm if clinically necessary. |
| What equipment is necessary for pressure measurements during the procedure? | Vascular pressure transducer to measure the portosystemic pressure gradient. To obtain this gradient, pressures are obtained in the right atrium and in the accessed portal vein. |
| What is the most commonly used stent-graft for TIPS procedures? | *GORE VIATORR* TIPS Endoprosthesis. |
| Most modern TIPS stents are partially covered and partially uncovered. What is the most appropriate orientation for the bare portion of the stent? | The uncovered portion of the stent should sit in the portal side of the tract. A radiopaque band on the stent-graft should indicate the transition point between covered and uncovered stent. |

## General Step by Step

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| Where is the most common site of initial access? | Right internal jugular vein via ultrasound-guidance. |

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| Which vessel is initially catheterized in the liver? | Hepatic vein, usually the right. |
| What is the sequence of steps that precede a portal venogram? | Wedged hepatic venogram (with contrast or CO2), then puncture from hepatic vein to intrahepatic portal vein, followed by a portal venogram. |
| What is the purpose of the portal venogram? | To assess the patency of the main portal vein & major feeding vessels (splenic vein and superior mesenteric vein), and the presence or absence of varices. |
| After confirming the patency of the portal vein, a pressure gradient is then measured between which two structures prior to advancing with the TIPS procedure? | Mean pressure gradient between the portal vein and right atrium. |
| Which step may need to be performed prior to deployment of the stent graft? | Dilation of the intrahepatic parenchymal tract, typically with a 3–4 cm length balloon. |
| What are the target gradient goals for variceal bleeding and refractory ascites? | If the indication is for variceal bleeding, the target is < 12 mmHg. If the indication is for refractory ascites, an approximately 50% reduction from the initial gradient measurement may correspond well with TIPS efficacy. However, some operators use < 12 mmHg as a target goal for refractory ascites as well. Depending on these measurements, further shunt dilation can be performed to achieve target goals. |

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| What additional step should be considered in patients whose indication for TIPS is variceal bleeding? | Embolization of varices. |
| What is the final run you should document for the procedure? | Completion portal venogram demonstrating shunt patency. |

## Complications

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| What is the peri-procedural mortality risk for the procedure? | There is a 1% peri-procedural mortality risk for the TIPS procedure. |
| What are some major acute postprocedural complications following a TIPS procedure? | Cardiac decompensation, acceleration of liver failure, intraperitoneal bleeding, and hepatic encephalopathy. |
| Which patients are most at risk for encephalopathy following the procedure? | Patients with baseline poor hepatic synthetic function. Encephalopathy is related to increased CNS exposure to ammonia following TIPS. |
| What are the major causes of post-procedural intraperitoneal bleeding? | Hepatic capsular perforation or extra-hepatic portal puncture. |

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| What is the relationship between TIPS complications and the patient's MELD (Model for End-Stage Liver Disease) score? | MELD 0–12 is low risk, MELD 13–17 is some risk, MELD 18–25 is high risk, MELD > 25 indicates TIPS to be used for compassionate care only. |
| What is the most common cause of long-term TIPS failure? | Graft stenosis. |
| Which are expected ultrasound features of TIPS evaluation? | Expected blood flow through a TIPS stent is toward the heart. Normal hepatopedal flow through the right and left portal veins may change to hepatofugal (retrograde) due to new, preferential flow through the low-resistance shunt. US findings – hepatopedal flow – portal vein to hepatic vein, velocities between 80 and 180 cm/sec. |
| Which portion of the graft is most likely to develop stenosis? | Hepatic vein side (cephalic) > mid-graft stenosis > portal vein side (caudal). Signs of cephalic stenosis are decreased main portal vein and midshunt velocities, especially if they are progressively decreasing on the follow-up exam. Velocity at the stenotic segment will be increased (often >200 cm/s) and demonstrate aliasing. It is important to note that the length of the stenotic segment between the hepatic vein and IVC is variable. |
| What are signs of TIPS shunt severe stenosis or occlusion? | Acute variceal hemorrhage and reaccumulating ascites. |

## Landmark Research

Colapinto, Rf, et al. "Formation of Intrahepatic Portosystemic Shunts Using a Balloon Dilatation Catheter: Preliminary Clinical Experience." *American Journal of Roentgenology*, vol. 140, no. 4, 1983, pp. 709–714., doi:https://doi.org/10.2214/ajr.140.4.709.

- This research in the early 1980s demonstrated the use of balloon dilation to improve effectiveness and patency of a portosystemic shunt created in the liver.

García-Pagán, Juan Carlos, et al. "Early Use of TIPS in Patients with Cirrhosis and Variceal Bleeding." *New England Journal of Medicine*, vol. 362, no. 25, 2010, pp. 2370–2379.

- Treatment of recurrent or refractory variceal bleeding in patients with advanced liver disease can still have a poor prognosis following a rescue TIPS procedure. This study demonstrates potential benefit of having a lower threshold for earlier TIPS placement in these patients in order to achieve better long-term outcomes.

Laberge, J M, et al. "Creation of Transjugular Intrahepatic Portosystemic Shunts with the Wallstent Endoprosthesis: Results in 100 Patients." *Radiology*, vol. 187, no. 2, 1 May 1993, pp. 413–420.

- One of the first large group (100 patient) studies in the early 1990s establishing the effectiveness of TIPS as a "reliable means of lowering portal pressure and controlling variceal bleeding."

Ochs, Andreas, et al. "The Transjugular Intrahepatic Portosystemic Stent–Shunt Procedure for Refractory Ascites." *New England Journal of Medicine*, vol. 332, no. 23, 4 May 1995, pp. 1192–1197.

- Prospective study clearly demonstrating effectiveness of TIPS to treat refractory ascites.

Palmaz, Jc, et al. "Expandable Intrahepatic Portacaval Shunt Stents: Early Experience in the Dog." *American Journal of Roentgenology*, vol. 145, no. 4, 1985, pp. 821–825.

- Early work in dogs in the mid-80s demonstrating the use of expandable stents within a portosystemic tract in liver parenchyma, which helped lay groundwork for more long-term tract patency when implemented in human subjects.

Perarnau, Jean Marc, et al. "Covered vs. Uncovered Stents for Transjugular Intrahepatic Portosystemic Shunt: A Randomized Controlled Trial." *Journal of Hepatology*, vol. 60, no. 5, 2014, pp. 962–968.

- Large, multicenter, randomized controlled trial comparing the effectiveness and patency of covered versus bare stents for TIPS creation. Findings showed a 39% reduction in stent dysfunction when using covered stents instead of bare stents.

Richter, Goetz M., et al. "Transjugular Intrahepatic Portacaval Stent Shunt: Preliminary Clinical Results." *Radiology*, vol. 174, no. 3, 1990, pp. 1027–1030.

- Early results from using balloon-expandable stents for TIPS in human patients, described as a "promising alternative to current therapy in high-risk patients with esophageal bleeding."

Rossle, Martin, et al. "The Transjugular Intrahepatic Portosystemic Stent-Shunt Procedure for Variceal Bleeding." *New England Journal of Medicine*, vol. 330, no. 3, 1994, pp. 165–171.

- Large-volume (n = 100) study demonstrating the effectiveness of TIPS for variceal bleeding in the setting of portal hypertension secondary to hepatic failure.

Rösch, J., et al. "Transjugular Intrahepatic Portacaval Shunt an Experimental Work." *The American Journal of Surgery*, vol. 121, no. 5, 1971, pp. 588–592.

- Initial description of the intentional percutaneous creation of an intrahepatic shunt between the systemic and portal circulation as an alternative to surgically created shunts for portal hypertension.

Sanyal, Arun J., et al. "Transjugular Intrahepatic Portosystemic Shunts Compared with Endoscopic Sclerotherapy for the Prevention of Recurrent Variceal Hemorrhage." *Annals of Internal Medicine*, vol. 126, no. 11, 1 June 1997, pp. 849–857.

- Randomized, controlled trial comparing the effectiveness of TIPS versus endoscopic sclerotherapy to prevent recurrent variceal bleeding. Study demonstrates equivalency over the long-term, with possible survival benefit with sclerotherapy.

## Common Questions

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| What is the target portosystemic gradient post-TIPS? | 8–12 mmHg. |
| What is the 1-year primary patency rate for bare-metal TIPS stents? | 50%. |
| What is the preferred modality for post-procedure TIPS surveillance/evaluation? | Interval follow-up Duplex ultrasound to confirm patency. Baseline evaluation should be obtained at 1 week for Wallstents and 1 month for covered stents. Follow-up ultrasound exams should then be obtained at 3 months after baseline and then every 6 months thereafter. |
| What is a normal TIPS velocity range? | 90–190 cm per second. |

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| If there is concern for stent malfunction, what is the next best step for diagnostic evaluation? | Venography. |
| What is the most common treatment for a thrombosed stent? | Balloon angioplasty and/or re-stenting. |
| What treatment options are available for a patient experiencing severe hepatic encephalopathy following a TIPS procedure? | Reduction of the TIPS shunt can be accomplished using a parallel stent technique in which covered and uncovered stents are placed in the existing stent. After the dilation of the covered stent, the uncovered stent can then be dilated to a desired diameter, which also narrows the diameter of the adjacent covered stent. |

## Further Reading

Colapinto RF, et al. Formation of intrahepatic portosystemic shunts using a balloon dilatation catheter: preliminary clinical experience. Am J Roentgenol. 1983;140(4):709–14.

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# Chapter 39
# Balloon-Occluded Retrograde Transvenous Obliteration (BRTO)

**Rupal Parikh**

## Evaluating the Patient

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| What is BRTO? | Balloon-occluded retrograde transvenous obliteration is an endovascular technique used to treat gastric varices, particularly when endoscopy fails or in patients with contraindications to a transjugular intrahepatic portosystemic shunt (TIPS) procedure. BRTO dates back to 1984 when it was called "transrenal-vein reflux ethanol sclerosis" and was subsequently refined in Japan. |
| What are the common indications for BRTO? | BRTO is used as a therapeutic adjunct or alternative to TIPS in patients with isolated gastric varices and in patients with a de novo portosystemic shunt complicated by hepatic encephalopathy. Thus, BRTO is performed in patients with encephalopathy post-TIPS but can also be performed in patients with isolated gastric varices, such as in patients with splenic vein thrombosis. |

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| What percentage of patients with cirrhosis develop variceal bleeding? | Approximately 30% of patients with cirrhosis develop variceal bleeding and of those, approximately 10–20% are gastric variceal bleeding. |
| What are the advantages of BRTO over TIPS? | BRTO is less invasive than a TIPS procedure and can be utilized in patients with hepatic encephalopathy and diminished hepatic reserve, suggesting a liver protective role. TIPS is less efficacious in treating gastric varices as compared with esophageal varices. |
| What causes gastric varices? | Portal hypertension and portal vein thrombosis secondary to cirrhosis result in back pressure from hepatofugal flow, creating shunts, such as gastrorenal and gastrocaval shunts, which feed gastric varices. |
| Which gastric varices are prone to rupture? | Hematemesis is one of the signs of actively bleeding gastric varices. Hemodynamically unstable patients must be clinically stabilized with intravenous fluid and blood transfusion while preventing volume overload or exacerbating portal hypertension. Varices at high risk for rupture are those that are large, rapidly growing, and with red spots on endoscopy. |
| What imaging studies are useful in the evaluation of suspected gastric varices? | Endoscopy with or without endoscopic ultrasound (EUS) is the initial diagnostic and therapeutic step in the evaluation of gastric varices. In addition, triple-phase computed tomography (CT) or enhanced magnetic resonance angiography/venography (MRA/MRV) without enteric contrast can be used to delineate the anatomy of the gastric varices. |
| How is a patient with esophageal varices and high flow gastric varices treated? | Endoscopic variceal banding should precede BRTO as BRTO can exacerbate esophageal varices. |

## High Yield History

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| What is the most common cause of upper gastrointestinal bleeding in patients with portal hypertension? | Esophageal followed by gastric varices are the most common cause of upper gastrointestinal bleeding in patients with a history of portal hypertension. |
| What is the Child-Pugh score? | The Child-Pugh score is based on the presence of ascites, presence of hepatic encephalopathy, total bilirubin, albumin, and prothrombin time/INR to determine the severity of liver dysfunction. |

| **Factor** | **1 point** | **2 points** | **3 points** |
|---|---|---|---|
| Ascites | None | Mild | Moderate/ Severe |
| Hepatic encephalopathy | None | Grade 1 or 2 | Grade 3 or 4 |
| Total bilirubin (mg/ mL) | < 2 | 2–3 | > 3 |
| Albumin (mg/mL) | > 3.5 | 2.8–3.5 | < 2.8 |
| PT (s) [or INR] | < 4 [< 1.7] | 4–6 [1.71–2.30] | > 6 [> 2.30] |
| Severity of cirrhosis | | | |
| Child-Pugh A | | 5–6 points | |
| Child-Pugh B | | 7–9 points | |
| Child-Pugh C | | 10–15 points | |

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| What is the model for end-stage liver disease (MELD) score? | The MELD score is a calculation based on total bilirubin, creatinine, and INR to determine the severity of liver dysfunction and determine ranking for liver transplantation. Serum sodium was later added to the calculation, which is referred to as the MELD-Na score. |
| What veins form the portal vein? | The splenic vein, superior mesenteric vein, and the right and left gastric veins come together to form the portal vein. Infrequently, the inferior mesenteric vein also drains into the portal vein. The left renal vein drains directly into the inferior vena cava and provides an alternative route of drainage in patients with portal hypertension who have developed gastrorenal shunts. |
| What is a transjugular intrahepatic portosystemic shunt (TIPS)? | TIPS is an endovascular treatment to decompress the portal venous system by placing a stent between the portal and hepatic veins in patients with refractory ascites or variceal bleeding. |
| How are gastric varices from splenic vein thrombosis different from those secondary to portal hypertension? | Gastric varices secondary to splenic vein thrombosis tend to involve multiple short gastric veins along the greater curvature of the stomach whereas those secondary to portal hypertension are more likely to involve gastrorenal or gastrocaval shunts in the fundus. |
| What are the most common causes of splenic vein thrombosis? | The most common causes of splenic vein thrombosis include pancreatitis, local malignancy, and splenectomy. Treatment options for gastric varices secondary to splenic vein thrombosis include splenectomy and splenic artery embolization. |

## Indications/Contraindications

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| When would BRTO be indicated? | BRTO is used as an adjunct/alternative to TIPS in patients with gastric varices and in patients with a de novo portosystemic shunt complicated by hepatic encephalopathy. Large fundic or cardiac gastric varices with high flow may be treated with BRTO as opposed to endoscopic treatment due to the increased risk of systemic delivery of sclerosant with endoscopic management. |
| How does the presence of portal vein thrombosis affect the management of gastric varices? | In portal vein thrombosis, gastrorenal and gastrocaval shunts are the pathways by which venous return from the splenic and mesenteric vasculature occurs. By embolizing these shunts, the mechanism by which the splenic and mesenteric systems drain would be eliminated. This can lead to mesenteric venous hypertension, mesenteric ischemia, and mesenteric thrombosis, particularly in the absence of other collateral vessel formation (i.e., cavernous transformation). |
| How does the presence of a diminutive/narrow portal vein affect the management of gastric varices? | BRTO will increase hepatopetal flow and thus flow through the portal vein would be increased and potentially overwhelmed. |
| What effect does BRTO have on pre-existing abdominal ascites? | BRTO can exacerbate abdominal ascites in patients with decompensated liver failure. Thus, a risk-benefit discussion should be had regarding the possibility of future TIPS placement. |

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| What are additional contraindications for BRTO? | Additional contraindications include severe coagulopathy, portal vein thrombosis, and uncontrolled esophageal variceal bleeding. |
| What is the most important determinant in survival post-BRTO? | Hepatic reserve followed by hepatocellular carcinoma (HCC) is the most important factor in determining survival after BRTO. Some consider HCC greater than 5 cm a contraindication to BRTO. |

## Relevant Anatomy

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| How is a gastrorenal shunt accessed? | Using either transjugular or transfemoral approach, the left renal vein is catheterized to access the gastrorenal shunt. |
| What are other non-conventional methods of accessing a gastric-variceal system? | Alternative approaches to accessing a gastric-variceal system include transcaval, trans-phrenic, trans-pericardiac, trans-ieocolic, trans-TIPS, trans-gonadal, trans-azygous, and trans-renal capsular vein. |
| What are the common inflow vessels? | The left gastric vein, posterior gastric vein, and short gastric veins are the most common afferent veins. |
| What are the most common types of shunts/varices? | Gastrorenal and gastrocaval varices are the most common types of shunts. Gastrorenal shunts provide venous outflow in 90% of cases. |

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| How are gastroesphageal varices anatomically classified? | One commonly used method to classify gastric varices is Sarin's classification, an endoscopic-based approach. Varices are classified into gastroesophageal (GOV) and isolated gastric (IGV) varices. Gastroesophageal varices are divided into varices present along the lesser (GOV1; 70% of GV) versus greater curvatures (GOV2; 20% of GV). Both GOV1 and GOV2 arise from the left gastric vein and drain to the IVC via the subdiaphragmatic left vein. Isolated gastric varices are divided into varices along the fundus (IGV1; 7% of GV) and along the body or antrum (IGV2; 2% of GV). IGVs arise from short gastric veins or the posterior gastric vein and may drain into the IVC via the left subdiaphragmatic vein or left renal vein via a gastrorenal shunt. GOV2 and IGV1 are fundic varices. GOV1 account for 20% of gastric variceal bleeding, whereas fundic varices (30% of GV) account for 70% of gastric variceal bleeding. |
| What afferent veins are in close proximity to GOV1/2 and IGV1 varices and should be embolized prior to GV sclerosis? | Inferior phrenic veins. |

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| What are the different types of venous drainage patterns of a varix? | Venous drainage patterns are categorized as type A through D. Type A has a single draining vein, such as a gastrorenal shunt and less commonly a gastrocaval shunt. This is the simplest type of shunt. Type B has a single shunt with multiple draining veins that lead to the IVC/right atrium. Type C has a gastrocaval and gastrorenal shunt. Type D, which is not amenable to BRTO, has multiple draining veins without a shunt. |
| What are the different types of Type B varices? | There are B1 and B2 varices, in which the collateral draining veins are small to medium in size and/or numerous. Type B3 varices have larger collateral veins, which can be selected and embolized with coils prior to variceal obliteration. |
| What are the different types of Type C varices? | There are C1 and C2 varices. C1 varices have a small shunt size. C2 varices have a large shunt size. |
| What are the different draining veins? | Draining veins include pericardiophrenic, ascending lumbar, intercostal, perivertebral, and least commonly, the azygous vein. |
| What are the different venous inflow patterns? | Varices can also be classified based on venous inflow patterns, types 1–3. In type 1 varices, there is a single afferent gastric vein (i.e., the left or posterior gastric vein). In type 2 varices, there are multiple afferent gastric veins (i.e., left and posterior gastric veins). In type 3 varices, an afferent vein(s) drains into the shunt without contributing to the gastric varix. |

## Relevant Materials

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| What is the purpose of using an occlusion balloon? | An occlusion balloon aids in diagnostic evaluation of the gastric-variceal system/complex by occluding the gastrorenal/gastrocaval shunt. An occlusion balloon also aids in the therapeutic sclerosis of the varix by minimizing reflux of sclerosant into the systemic or portal systems. |
| What materials are commonly used as sclerosant? | The original sclerosant utilized was ethanolamine oleate iopamidol (EOI), which is a hemolytic agent. Sodium tetradecyl sulfate (STS) and polidocanol are also sclerosants with 3% STS being the most frequently utilized sclerosant in the United States. Foam versions of these sclerosants have better variceal wall contact and require potentially less dose of sclerosant. |
| How do foam sclerosants form better variceal wall contact? | Foam sclerosants displace blood volume, rise anti-gravitationally into the varix, and also have a greater surface area for variceal wall contact. Expansion of the sclerosant with Tessari methods (mixture of air with sclerosant) allows for greater treatment with less dose. Foam sclerosants are also used to treat lower extremity varicose veins. |
| What are the foam sclerosants mixed with? | STS is mixed with room air as well as lipiodol for visualization in a ratio of 2 mL of STS, 1 mL of lipiodol, and 3 mL air. A foam version of EOI consists of 10 mL of 10% ethanolamine oleate mixed with 10 mL of iodinated contrast, 20 mL of air, and 2 mL 3% foam polidocanol. |

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| How is selective embolization performed? | A microcatheter can be advanced through the occlusion balloon and positioned near the afferent vein to facilitate the reflux of the sclerosant, limiting the amount of sclerosant needed and reducing the risk of balloon rupture by spatially separating the balloon from the sclerosant. |
| How is the embolization monitored? | Intermittent fluoroscopy is used to monitor the delivery and stagnation of sclerosant within the varix. In anatomically challenging cases, cone-beam CT may also be used. |
| What are newer modifications to the classic BRTO technique? | Modified techniques include vascular plug-assisted retrograde transvenous obliteration (PARTO), coil-assisted retrograde transvenous obliteration (CARTO), and balloon-occluded antegrade transvenous obliteration (BATO). |
| What follow-up imaging is performed? | CT venography, MRV, or EUS can be used for follow-up imaging to assess for variceal obliteration. Follow-up with endoscopy is also performed, particularly in cases of exacerbated esophageal varices. |
| What preprocedural antibiotics are administered? | Antibiotics prophylaxis is determined based on local resistance patterns; however, intravenous ceftriaxone 1 gram per day for no more than 7 days is currently recommended. Fluoroquinolones have also been used for gastrointestinal coverage. |

## General Step by Step

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| What is the most common access approach for BRTO? | Although right internal jugular approach can be used, right femoral venous approach is the most common. Patient anatomy must be taken into account when determining which approach is more favorable. |

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| How is the size of the occlusion balloon selected? | The diameter of the occlusion balloon is based on the size of the communicating gastrorenal shunt at the intended site of balloon occlusion, typically 6–20 mm. This is measured by assessing the diameter of the base of the shunt where it joins the left renal vein. Additional areas of narrowing within the shunt are also assessed for optimal balloon placement. Occlusion balloon placement is dependent on diameter and stability. |
| How are C1 varices treated differently from C2 varices? | C1 varices are catheterized through a gastrorenal shunt and are coil embolized followed by delivery of sclerosant into the shunt/varix. C2 varices are treated by inflating one occlusion balloon in the gastrorenal shunt and another in the gastrocaval shunt, which can be positioned via an internal jugular approach. Sclerosant is then administered to the shunt/varix. |
| How are type 1 varices treated? | Type 1 varices are treated by administering sclerosant into the varix with eventual stagnation due to back pressure from the portal circulation. It is critical to control manual pressure of injection as to not exceed the back pressure from the portal system. |
| What is important to keep in mind when treating type 2 varices? | In type 2 varices, the two afferent vessels may have differential pressures that lead to the reflux of sclerosant into the lower pressure system at the point of stagnation within the varix. However, because of the reflux out of the higher pressure system, the higher pressure afferent vein remains patent and will persistently feed a portion of the varix, resulting in only partial obliteration. This requires a second BRTO. |

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| How are Type 3 varices treated? | Type 3 varices are treated by advancing a microcatheter into the gastric varix and administering sclerosant in a way that prevents reflux into the afferent vein. If this is not feasible, the afferent vein should be embolized either percutaneously or via transjugular approach prior to embolizing the varix. |
| What are the general steps involved with BRTO? | Utilizing standard angiographic technique, the right internal jugular or right femoral vein is accessed percutaneously. The gastrorenal shunt is then accessed by catheterizing the left renal vein using a diagnostic catheter (e.g., Cobra catheter) placed in the inferior vena cava or distal renal vein via a 6–12 Fr access sheath. A 0.035 wire is advanced into the shunt followed by exchange of the diagnostic catheter for an occlusion balloon ranging from 8.5 to 32 mm (e.g., Python). The occlusion balloon is positioned at a narrowing within the shunt and inflated. A retrograde venogram with or without Cone-Beam CT is performed to determine the anatomy of the varix. The microcatheter is then advanced through the balloon catheter as proximally as possible and the sclerosant mixture is then delivered to the shunt/varix under fluoroscopic guidance. |

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| What is the endpoint of BRTO? | Technical success is considered when there is embolization of the varix with minimal filling of the afferent vein (i.e., posterior gastric vein) or portal vasculature. Post-procedure cone-beam CT can be utilized to ensure sclerosis. |
| How long is the occlusion balloon kept inflated? | Occlusion balloon inflation times vary from 1 to 24 hours and are released under fluoroscopy. |

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| What are the steps to manage a shunt that is too large to occlude with a balloon catheter? | Partial splenic vein embolization can be attempted to decrease the size of the shunt 2 weeks prior to BRTO. |
| How are leaking collateral veins treated? | Collateral veins can shunt blood flow away from the varix, limiting the technical success of embolization. These can be occluded with coils or Gelfoam if necessary. When there are different pressure gradients of multiple afferent veins, repeat BRTO may be necessary to address excessive reflux of the sclerosant into the lower pressure pathway and residual patency of the high pressure pathways. |

## Complications

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| What are the most common complications following BRTO? | BRTO patients are medically complex and require a multi-disciplinary approach. Many reported complications, such as fever, hemoglobinurua, chest pain, epigastric pain, and back pain are self-limited or require supportive care. Excessive reflux of the sclerosant into the portal system may lead to thrombosis-related complications. Ascites and esophageal varices may be exacerbated. |

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| What prophylaxis is utilized for sclerosant-induced hemolysis? | EOI, which is not FDA approved in the United States, can induce hemolysis. For these patients, 4000U of haptoglobin is administered intraprocedurally to bind free hemoglobin released by EOI-induced hemolysis. This minimizes renal tubular disturbances and risk of acute renal failure. The foam version of EOI can minimize the dose delivered and thus minimize the risks of BRTO. Additionally, EOI can also be delivered in aliquots in multiple BRTO sessions to decrease the risk of hemolysis-related renal failure. |
| What additional adverse outcomes are associated with EOI administration? | EOI can lead to cardiogenic shock, pulmonary edema, and disseminated intravascular coagulation. The total volume of EOI should be limited to 40 mL per procedure. |
| What additional adverse outcomes are associated with BRTO? | Balloon rupture, possibly due to direct contact with the sclerosant, during or after embolization can result in pulmonary embolism, systemic delivery of sclerosant, and increased mortality. BRTO can also result in increased portal hypertension leading to exacerbation of esophageal varices and ascites as well as fulminate hepatic failure. |
| What additional complication can arise from the use of foam sclerosants? | Air embolism to the pulmonary circulation or to the systemic circulation via a patent foramen ovale can result from the use of foam sclerosants. |

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| What are the long-term complications of BRTO? | Long-term complications include potential development of portal hypertensive gastropathy with the formation of and bleeding from esophageal/duodenal varices, worsening of liver function in patients with poor hepatic reserve and development of ascites or hydrothorax, spontaneous bacterial peritonitis, and portal/renal vein thrombosis. |
| What factors contribute to technical failure? | Type I: inability to access the gastrorenal shunt due to tortuosity or absence of shunt; extravasation of sclerosant |
| | Type II: large shunt size leading to inadequate occlusion of the gastrorenal shunt |
| | Type III (most common): extensively leaking collateral veins that cannot be selectively catheterized |
| | Type IV: balloon rupture |

## Landmark Research

Prevalence, classification, and natural history of gastric varices: a long-term follow-up study in 568 portal hypertension patients

Sarin SK, Lahoti D, Saxena SP, Murthy NS, Makwana UK. Prevalence, classification and natural history of gastric varices: a long-term follow-up study in 568 portal hypertension patients. Hepatology. 1992;16 (6):1343–1349.

- Prospective review of 568 patients with gastric varices secondary to portal hypertension
- Gastric varices seen in 20% of patients at presentation and 9% of patients after treatment of esophageal varices
- Gastric varices less likely to bleed but more likely to bleed significantly and have a higher mortality when compared to esophageal varices

- Classification of gastric varices by Sarin's classification system as detailed above

Long-term results of balloon-occluded retrograde transvenous obliteration for the treatment of gastric varices and hepatic encephalopathy

Fukuda T, Hirota S, Sugimura K. Long-term results of balloon-occluded retrograde transvenous obliteration for the treatment of gastric varices and hepatic encephalopathy. J Vasc Interv Radiol. 2001;12 (3):327–336.

- Restrospective review of 43 patients status post BRTO
- Gastric varices disappeared or significantly decreased in size with the resolution of hepatic encephalopathy in 11/11 patients post BRTO
- Improvement in Child-Pugh score in 11% of patients on follow-up at 1 year with relapse-free survival at 3 years of 87.4%
- Exacerbation of esophageal varices in 8 patients
- Most significant prognostic factor: Child-Pugh score

Balloon-occluded retrograde transvenous obliteration versus transjugular intrahepatic portosystemic shunt for the treatment of gastric varices due to portal hypertension: A meta-analysis

Wang Y.B., Zhang J.Y., Gong J.P., Zhang F., Zhao Y. Balloon-occluded retrograde transvenous obliteration versus transjugular intrahepatic portosystemic shunt for treatment of gastric varices due to portal hypertension: a meta-analysis. J Gastroenterol Hepatol. 2016;31:727–733.

- Meta-analysis of 5 randomized control trials and cohort studies comparing TIPS with BRTO for treatment of gastric varices
- No statistically significant difference in technical success rate, hemostasis rate, and incidence of procedure-related complication
- Lower incidence of re-bleeding and post-operative encephalopathy in BRTO

Balloon-occluded retrograde transvenous obliteration (BRTO) for the treatment of gastric varices: review and meta-analysis

Park J.K., Saab S., Kee S.T., Busuttil R.W., Kim H.J., Durazo F. Balloon-occluded retrograde transvenous obliteration (BRTO) for treatment of gastric varices: review and meta-analysis. Dig Dis Sci. 2015;60:1543–1553.

- Meta-analysis of 24 studies with a total of 1016 patients with acute bleeding or at-risk gastric varices treated with BRTO
- Technical success rate of 96.4% with clinical success rate (absence of recurrence/rebleeding or variceal obliteration) of 97.3%
- Major complication rate of 2.6% with esophageal variceal recurrence rate of 33.3%

Treatment of patients with gastric variceal hemorrhage: endoscopic N-butyl-2-cyanoacrylate injection versus balloon-occluded retrograde transvenous obliteration

Hong C.H., Kim H.J., Park J.H., Park D.I., Cho Y.K., Sohn C.I. Treatment of patients with gastric variceal hemorrhage: endoscopic N-butyl-2-cyanoacrylate injection versus balloon-occluded retrograde transvenous obliteration. J Gastroenterol Hepatol. 2009;24:372–378.

- Retrospective review of 14 patients treated with endoscopic sclerosant injection and 13 patients treated with BRTO
- Higher risk of rebleeding after endoscopic sclerosant therapy compared to BRTO (71.4% versus 15.4%) with no rebleeding in 6/6 patients treated with rescue BRTO

## Common Questions

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| What is BRTO? | Balloon-occluded retrograde transvenous obliteration is an endovascular technique used to treat gastric varices, particularly when endoscopy fails or in patients with contraindications to a transjugular intrahepatic portosystemic shunt (TIPS) procedure. |
| Who is considered the inventor BRTO? | Many consider Kanagawa as the inventor of BRTO, though the first published attempt at balloon-occluded sclerotherapy of the gastrorenal shunt for the management of gastric varices was authored by Olson et al. in 1984. |
| What must the IR physician be sensitive to regarding patient stabilization prior to BRTO? | Overly aggressive fluid resuscitation can exacerbate portal hypertension. Therefore, lower than normal systemic blood pressures (and associated lower targets in goal hematocrit and platelet count) are tolerated. |
| Which vessels serve as the primary outflow for the splenic and mesenteric veins in the presence of main portal vein thrombosis? | Gastrorenal shunts |
| What caution must be taken in the presence of a very diminutive portal vein? | A diminutive portal vein may be overwhelmed by the BRTO procedure. This can lead to flow stagnation and portal vein thrombosis. |
| What essential knowledge is needed prior to a BRTO procedure? | Shunt anatomy and sizes, areas of narrowing, and available balloon-occlusion catheter inventory |

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| What are benefits to using cone beam CT during the BRTO procedure? | The goal of balloon occlusion venography is to opacify the entire gastric-variceal system, including all afferent veins, as well as efferent veins that decompress the system. Cone beam CT can be used to better visualize this anatomy and can be particularly helpful for novice operators. |
| What is the endpoint of BRTO? | Technical success is considered when there is embolization of the varix with minimal filling of the afferent vein or portal vasculature. |

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# Part VI
# Genitourinary

# Chapter 40
# Percutaneous Nephrostomy

**Marco Ertreo and Ifechi Momah**

## Evaluating the Patient

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| What patient position must be maintained during a percutaneous nephrostomy procedure? | Percutaneous nephrostomy catheter placement is performed with the patient in the prone or prone-oblique position. |
| Why is it important to evaluate for signs of infection? | Urinary obstruction with superimposed infection requires emergent decompression. |
| How do you diagnose pyonephrosis? | Flank pain, fever, leukocytosis, and collecting system dilatation on imaging. |
| Should pertinent imaging be available and why? What valuable information can be obtained from cross sectional imaging? | Yes, to confirm the diagnosis and determine optimal approach to the renal collecting system. The level of obstruction and potential cause may also be deduced. |
| What laboratory studies should be available? | CBC, BMP, urinary analysis, and coagulatory profile. |

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| What category of bleeding risk do SIR Standards of Practice Committee assign to percutaneous renal interventions? | Category 3: Significant bleeding risk, difficult to control or detect. |
| Is coagulopathy an absolute or relative contraindication? | Relative. |
| What INR is recommended prior to starting the procedure? | Below 1.5–1.8. |
| What platelet count is recommended prior to starting the procedure? | Above 50,000/$mm^3$. |

## High Yield History

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| Is chronic unilateral obstruction due to malignancy an indication for emergent percutaneous nephrostomy? | Not unless there are signs of urosepsis. |
| What are risk factors for pyonephrosis? | Diabetes, immunosuppression, urinary tract obstruction, or anatomical predisposition (horseshoe or pelvic kidney, duplicated collecting system), |
| What should be considered if the patient is ASA 3, has difficulty with prone positioning, or experiences respiratory compromise while prone? | Anesthesiology consultation. |

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| What kidney should undergo nephrostomy if there is bilateral obstruction? | Both kidneys may be considered for nephrostomy placement, depending on how long they have been obstructed and how much estimated functioning parenchyma remains. |
| How can the function of each kidney be assessed? | With a renal scintigraphy or "renal scan," performed in the nuclear medicine department. This is performed following the intravenous injection of radiopharmaceuticals or tracers that allow the evaluation of different aspects of renal function, such as renal blood flow, glomerular filtration rate, effective renal plasma flow, renal tubular flow, and excretory function. The most commonly used *radiopharmaceutical is* Tc-99 m-MAG3 (technetium 99 mercaptoacetyltriglycine) and it allows evaluation of blood flow, renal function, and excretion; Tc-99 m DTPA (diethylenetriamine penta-acetic acid) is used for GFR calculation, and Tc-99 m-DMSA (dimercaptosuccinic acid) is typically used to assess for scarring and renal viability. When assessing for renal function, a normally functioning kidney will demonstrate, in order, normal perfusion, good cortical uptake, corticomedullary transit, and clearance without pooling in the collecting system. A poorly functioning kidney can have decreased cortical uptake or corticomedullary transit and even decreased blood flow in more advanced cases. In cases of obstructive hydronephrosis, urine will pool within the collecting system and ureter. Renal scintigraphy also allows the calculation of the percentage of renal clearance that is performed by each kidney, which should be split almost evenly in a healthy patient. This functional information can aid the IR in determining which kidney should undergo nephrostomy placement. |

## Indications/Contraindications

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| What are the indications for percutaneous nephrostomy? | Percutaneous nephrostomy allows access to the renal collecting system, typically to relieve urinary obstruction in the emergent/urgent setting in a septic patient, although it can also be used for: gaining access to the collecting system in order to perform other percutaneous interventions (such as antegrade ureteroplasty of a stricture, ureteral stenting, ureteral occlusion, lithotripsy) or to divert urinary flow (in the setting of a urinoma, urinary leak or fistula). |
| What does long-standing collecting system dilatation (hydronephrosis) cause? | Loss of nephrons, atrophy, and eventual loss of renal function. |
| What are the main causes of ureteral obstruction? | Ureteric stones, urinary malignancies (ureter, prostate, bladder), invasion by adjacent neoplasms, metastatic implants, post-surgical and post-radiation strictures, and retroperitoneal fibrosis. |
| When should the procedure be performed? | As soon as possible after the diagnosis of obstruction. |
| When is emergent decompression indicated? | When there are signs of sepsis, indicating pyonephrosis. |
| What are contraindications to the procedure? | Uncorrectable coagulopathy and patients unable to cooperate with the procedure (inability to lay prone or severe respiratory distress). Contrast allergy is a relative contraindication. |

## Relevant Anatomy

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| In what space are the kidneys located? | The kidneys are retroperitoneal structures, contained within the perirenal space. The perirenal space is bounded by the renal fascia, which is divided into the anterior perirrenal fascia or Gerota's fascia and posterior perirenal fascia or Zuckerkandl's fascia. Anterior to the perirenal space is the anterior pararenal space. This space crosses the midline and contains the duodenum, pancreas, and the retroperitoneal portions of the ascending and descending colon. The posterior pararenal space is located posterior to the perirenal space and contains only vessels, lymphatics and fat. |
| To what level does the posterior pleura typically extend? | 11th–12th rib. |
| Why is this important and what potential complication can develop with upper pole access? | It is important because the pleura could be potentially punctured during nephrostomy access, increasing the risk of pneumothorax. Traversing the 11th intercostal space or above it carries a higher risk of pneumothorax. If upper pole access and/or puncture through the 11th intercostal space is needed, pre-procedural cross-sectional imaging should be obtained. |
| What structure can be located posterior to the kidney? | The colon. Care should be taken to evaluate for colonic positioning before proceeding with nephrostomy placement. |
| In what order are the renal artery, vein, and pelvis situated at the hilum? | From anterior to posterior: renal vein, artery, and pelvis. |

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| How does the renal artery branch at the hilum? | Anterior and posterior divisions. |
| How many segmental branches does each division have? | Anterior division: 3–4; posterior division: 1. |
| What is the safest target for percutaneous nephrostomy placement? | Posterior calyx. |
| Can only posterior calyces be accessed? | No, any calyx can be accessed. For example, if the intent of obtaining access into the collecting system is to treat nephrolithiasis, then the calyx chosen should allow proper access to the stone to be treated (mid or upper pole for ureteral stone, which facilitates system navigation into the ureter). |
| What is Brodel's line and why is it important? | Brodel's line is a relatively avascular plane in the posterolateral kidney, between the distal anterior and posterior segmental branches of the renal artery; hence there is lower bleeding risk when crossing it with a needle when compared to other regions of the kidney. It is typically 30–45 degrees with respect to the table with the patient in the prone position. |
| Why should direct renal pelvis access be avoided? | Because there is greater risk of causing hemorrhage and urinoma. |

## Relevant Materials

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| What is a percutaneous nephrostomy catheter? | An external, self-retaining drainage catheter, which contains a distal Cope loop or tulip tip with locking mechanism that is positioned in the posterolateral renal collecting system through the patient's flank. |
| What size nephrostomy catheter is typically used in patients with clear urine? | 8–12 French |
| What size nephrostomy catheter should be used in patients with purulent urine? | 10–12 French |
| What size needle is used for initial access into the calyx? | 21–22 gauge |
| What initial guidewire size is used? | 0.018″ guidewire |
| What is typically used to access the calyx once the 0.018″ guidewire is placed? | A single-stick upsizing introducer system, such as Neff Set by Cook (Blooington, IN) or Accustick by Boston Scientific (Natick, MA). Introducer systems are used in non-vascular procedures for over-the-wire placement, which then allow the introduction of an 0.035–0.038″ guidewire for greater support. The system is a coaxial 4-Fr and 6-Fr dilator sheath with a stiffening and locking inner cannula. |

## General Step by Step

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| Should antibiotics be administered prior to the procedure? | Yes, except for routine catheter exchange in low-risk patients. Although there is no consensus regarding the first-choice antibiotic, suggested regimens include a single dose of 1–2 gm IV of ceftriaxone. Clindamycin and an aminoglycoside or vancomycin may be used in penicillin allergic patients. |
| What imaging technique is most commonly used for nephrostomy placement? | Ultrasound and/or fluoroscopy. Typically, initial access into the kidney is performed under sonographic guidance utilizing a curvilinear probe, which have a wide field of view and utilize lower frequencies, allowing for visualization of deeper tissues. Once access is confirmed, the procedure is completed under fluoroscopic guidance. |
| How should the patient be positioned? | Prone or prone-oblique with the side to be accessed elevated, preferably to 45 degrees. |
| Where is the ideal skin entry site? | Ipsilateral posterior axillary line, 2–3 cm below the 12th rib in order to avoid pleura. |
| What is the best angle for needle entry? | Approximately 30–45 degrees with respect to the table surface (along Brodel's line). |
| Besides with imaging, how can the operator confirm the needle has entered the renal parenchyma? | The needle tip will move synchronously with the patient's respirations. |

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| How do you confirm access into the collecting system? | Once the needle is in place, urine will flow out of the needle once the inner stylet is removed. The operator can also inject a minimal amount of contrast (1–3 ml) to opacify the collecting system, confirming placement. Only a small amount of contrast should be injected to avoid overdistention of the collecting system, which can cause bacterial translocation into the bloodstream and bacteremia. |
| Once the needle is in the collecting system, do you aspirate all the urine? | No, because you risk decompressing the pelvis, which limits your visualization of the collecting system and threatens loss of access. |
| What do you introduce through the needle after it is in the appropriate position? | The 0.018″ wire. |
| What is 0.018″ wire exchanged for? | The single stick introducer set (Neff or Accustick) and 0.038″ guidewire. |
| Sequential dilatation of the tract should be performed up to what size? | One French larger than the final catheter size. |
| Why is contrast injected at the end of the procedure? | To confirm correct catheter positioning |

## Complications

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| What is the most common complication following the placement of percutaneous nephrostomy? | Septic shock. Reported incidence rates range between 1% and 10% of cases, with lower incidence in the non-emergent setting (1–4%) and higher incidence in patients with pyonephrosis (7–9%). Of note, patients might already be septic at the beginning of the procedure when performed emergently. Septic shock can develop following the procedure or while the patient is on the procedural table. |
| How are sepsis and septic shock defined? | Sepsis is defined as life-threating organ dysfunction caused by a dysregulated response of the host to infection. Septic shock is a subset of sepsis where circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than sepsis alone. |
| What can be used to quickly assess if a patent with sepsis is likely to have a worse outcome? | Bedside assessment of a patient with suspected infection can be performed with the quickSOFA (qSOFA) score. The qSOFA score is a simplified version of the SOFA (Sequential Organ Failure Assessment) score, which can be used to determine the degree of organ dysfunction and mortality risk in ICU patients with suspected infection. The qSOFA score assigns a point to any Glasgow Come Score <15, respiratory rate above 22, and a systolic blood pressure <100 mmHg. A score of 2 or above is considered positive and suggests a higher risk of worse outcome. |

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| How should suspected sepsis be initially managed? | Initial management should focus on stabilizing the patient, focusing on securing the patient's airway if compromised, stabilizing breathing through oxygen supplementation and maintaining tissue perfusion/circulation through aggressive administration of intravenous fluids. Within the first hour, blood samples for baseline complete blood counts with differential, complete metabolic panel with lactate level, coagulation studies, and blood cultures should be obtained. The serum lactate level aids in determining the degree of sepsis (in combination with clinical and laboratory findings) and allows following the patient's response on subsequent draws. Within this time frame, intravenous empiric antibiotic treatment should also be administered. |
| What are potential complications with anterior access? | Hemorrhage, perforation of colon, spleen, and liver. |
| Risk for which complication is increased with upper pole access? | Pneumothorax. While small pneumothoraces might not be clinically evident and go unnoticed, larger pneumothoraces can cause shortness of breath, labored breathing, the use of accessory muscles during respiration, decreased saturation, and even hemodynamic compromise such as hypotension and tachycardia if a tension pneumothorax has developed. If a pneumothorax is suspected, the patient should be stabilized, and imaging should be obtained to confirm the diagnosis. Either a chest radiograph or sonography can be used (under ultrasound, the lung and pleural interfaces slide on each other, while with a pneumothorax the sliding is absent). |

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| Is hematuria common after the procedure? | Mild hematuria can occur following the procedure and it gradually clears within a few days. If the bleeding does not resolve or clear as expected, this may be due to venous oozing, often from the drain being partially retracted into the parenchymal tract. This can be addressed by either repositioning the drainage catheter further into the collecting system under fluoroscopic guidance, temporarily placing a balloon, or upsizing the drain to tamponade any small oozing vessels. Any time a drain is repositioned or exchanged, this should be done over an 0.035″ guidewire in order to provide adequate support and access |
| How does major bleeding present and how can it be treated? | Major bleeding requiring transfusion is rare (1–4% of cases) and presents as heavy arterial bleeding into the collecting bag with tachycardia and decreasing hemoglobin and hematocrit levels. The most common causes include injury to branches of the renal artery, creation of an arteriovenous fistula or pseudoaneurysm formation during catheter placement. While conservative management can be attempted, treatment of these complications will typically require renal angiogram and embolization with either coils, gelfoam or a combination. Reported rates of vascular injuries requiring endovascular treatment or even nephrectomy range between 0.1% and 1% of cases. |
| What exam should be ordered to diagnose active hemorrhage and potential causes? | CT angiogram of the abdomen, typically triple phase (unenhanced, arterial, and venous phases). This will allow for the evaluation of active bleeding and the culprit. If there is suspicion for a urine leak, additional delayed imaging can also be obtained to evaluate for contrast extravasation from the collecting system during the excretory phase of renal clearance. |

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| What other kinds of imaging technique can be used to diagnose a pseudoaneurysm and what are the expected findings? | Sonography can be used to visualize renal artery pseudoaneurysms, which presents as a hypoechoic focal dilatation of the renal artery with characteristic internal swirling pattern seen on color Doppler imaging, known as yin-yang sign. The swirling represents bidirectional flow within the aneurysmal sac. |

## Common Questions

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| What is pyonephrosis? | Urinary tract obstruction and accumulation of pus in the collecting system. |
| What is the most common bacteria isolated with pyonephrosis? | Escherichia Coli. |
| What is used to upsize after initial access? | A single stick upsizing introducer system (Accustick or Neff sets). |
| How often should a drain be routinely exchanged? | Every 6–8 weeks, unless it becomes dislodged or other complications arise sooner. |
| What is a PCN usually connected to? | Drainage bag. When connected only to a drainage bag, this is termed "external drainage." If the patient also has a nephroureteral stent, this is termed "internal-external drainage." If the patient only has a nephroureteral stent, this is termed "internal drainage." |

## Landmark Research

Dyer RB, Regan JD, Kavanagh P V., Khatod EG, Chen MY, Zagoria RJ. Percutaneous nephrostomy with extensions of the technique: Step by step 1. Radiographics 2002

- Access via percutaneous nephrostomy not only allows drainage of an obstructed collecting system but also allows interventionalists and urologists to perform multiple procedures (i.e., lithotripsy, stone removal, stent placement, tumor fulguration) in a minimally invasive fashion.
- Minor complications not requiring additional care can be seen in up to 25% of patients, while major complications are seen in 1–3% of patients.

Pieper CC, Meyer C, Hauser S, Wilhelm KE, Schild HH. Transrenal ureteral occlusion using the amplatzer vascular plug II: A new interventional treatment option for lower urinary tract fistulas. Cardiovasc Intervent Radiol. 2014

- Treatment of ureteral fistulas due to pelvic malignancy are difficult to treat surgically.
- Transrenal ureteral occlusion performed via percutaneous nephrostomy can be performed with different materials including coils, tissue adhesives, balloons and others, although can require additional interventions due to dislocation or recanalization. Utilization of Amplatzer vascular plugs with or without coils is equally efficacious and less prone to dislocation.

## Further Reading

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# Chapter 41
# Uterine Artery Embolization

**Ifechi Momah-Ukeh and Marco Ertreo**

## Evaluating the Patient

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| Collaboration with which specialty should be considered when evaluating a patient for UAE? | Gynecology. A multidisciplinary team approach is more likely to provide the patient with a thorough work-up and treatment plan. |
| What are symptoms associated with fibroids? | Heavy menstrual bleeding, pelvic pressure, pelvic pain, back pain, urinary urgency, urinary frequency, incontinence, and dyspareunia. |

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| What is the preferred imaging modality to assess the patient for fibroids? | MRI; studies have shown MRI to be superior to ultrasound in accurately detecting fibroids, evaluating fibroid location, and demonstrating abnormal enhancement. MRI has better interobserver reproducibility when compared to other modalities. Contrast-enhanced MRI has the advantage of producing an MRA that may be helpful in planning for UFE. Procedural success is unlikely if there is little or no enhancement of the fibroids. |
| Why is abnormal MRI enhancement worrisome? | Pelvic malignancy can mimic fibroid disease and imaging differentiation between fibroids and leiomyosarcoma can be challenging due to their overlapping features. Abnormal enhancement, hemorrhage, and myxoid degeneration on an MRI can sometimes suggest an invasive/malignant component within a uterine mass. |
| What symptoms should cause you to consider a uterine malignancy? | Patients with weight loss, fatigue, other systemic symptoms, or rapid growth of a single fibroid should be treated with hysterectomy due to concern for uterine malignancy.<br><br>Additionally, all patients over 40 years old with abnormal bleeding should undergo pap smear and endometrial evaluation (e.g., biopsy, hysteroscopy, dilation, and curettage) as part of the routine, pre-UFE workup for because endometrial carcinoma can coexist with fibroid disease and be a cause of menorrhagia. |

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| Describe the post-UFE follow-up? | Follow-up typically consists of an IR clinic visit and MRI; however, timing and specifics are institution dependent. Quality-of-life data suggest that most patients are symptomatically improved at 3 months post-UFE and this interval for follow-up can be utilized. Normal gynecologic well-woman care with a gynecologist should be continued. |

## High Yield History

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| What clinical tests/ procedure results should be reviewed when seeing a patient in consultation for fibroid embolization? | (a) Laboratory data (e.g., PT/INR, creatinine, hemoglobin/hematocrit, platelets) |
| | (b) Pelvic examination |
| | (c) Results of pap smear within 1 year |
| | (d) Endometrial biopsy if treating menorrhagia, especially if older than 40 years old |
| | (e) Pelvic imaging |
| What other gynecologic disorders overlap with uterine fibroids? | Endometriosis and adenomyosis. Adenomyosis is well-identified on T2 imaging and requires patient counseling on the decreased likelihood of treatment success. |
| What should patients be counseled on if desiring future fertility? | There is a 2–3% chance of early menopause. Although UFE is likely to preserve the uterus, for women who desire future childbearing, the long-term effects on the menstrual cycle and capacity for reproduction are unknown. |

## Indications/Contraindications

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| What is the most common indication for UAE? | Symptomatic fibroids. |
| What are other indications for UAE? | (a) Adenomyosis |
| | (b) Prepartum/preoperative interventions |
| | (c) Postpartum hemorrhage |
| | (d) Inoperable gynecologic tumors |
| | (e) Uterine vascular malformations |
| What are contraindications for UAE? | (a) Leiomyosarcoma or suspected gynecologic malignancy |
| | (b) Current gynecologic infection |
| | (c) Active pregnancy |
| What is the primary symptom causing women to seek treatment for fibroids? | Menorrhagia. |
| What are the contraindications of UAE for patients with life-threatening hemorrhage? | There are no contraindications. |

## Relevant Anatomy

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| What division of the internal iliac (hypogastric) artery does the uterine artery arise from? | Anterior division. |

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| What branch does the uterine artery directly arise from? | There is a wide variability in the origin of the uterine artery. Most commonly, the uterine artery is the first or second branch from the anterior division of the internal iliac artery. |
| What are the relevant segments of the uterine artery? | From proximal to distal, the uterine artery can be divided into descending, transverse, and ascending segments. |
| What small branches originate from the mid to distal uterine artery, typically from the transverse segment of the uterine artery? | Cervical-vaginal branches. |
| What is the common radiographic appearance of uterine arteries? | Hypertrophied tortuous corkscrew configuration coursing medially in the pelvis. |
| What is a common collateral blood supply to fibroids? | Ovarian arteries, which arise from the abdominal aorta inferior to the renal arteries and superior to the inferior mesenteric artery (between L2 and L3). |
| What is the classification of fibroids by location? | *Submucosal*: protrude into the endometrial cavity<br>*Intramural*: within the myometrium<br>*Subserosal*: protrude out of the serosal surface, covered by parietal peritoneum<br>*Pedunculated*: attached to the uterus by a stalk<br>*Cervical*: located in the uterine cervix |

## Relevant Materials

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| What embolic material is most commonly used for fibroids? | Particles such as trisacryl gelatin microspheres (Embosphere®) or polyvinyl alcohol particles (PVA). |
| What embolic material is most commonly used for uterine/vaginal hemorrhage? | Gelfoam slurry or pledgets |
| | Coils |
| | n-Butyl-2-cyanoacrylate (NBCA;glue) |
| What size catheters are typically used to select the uterine artery? | 4 or 5-Fr catheters or larger lumen microcatheters. |
| Why do some interventionalists prefer microcatheters over 4- or 5-Fr catheters? | A microcatheter occupies a smaller percentage of the cross-sectional area of the uterine artery and is softer with a more flexible tip, which may reduce the likelihood of catheter-induced spasm. |

## General Step by Step

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| What access sites are commonly used? | Unilateral common femoral artery |
| | Bilateral common femoral arteries |
| | Unilateral radial artery |
| Why are pelvic angiograms performed? | To map the uterine arteries. |

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| What is the most helpful view to identify the uterine artery? | Ipsilateral anterior oblique. |
| Where should the catheter tip be positioned for treatment? | Transverse portion of the uterine artery, and distal to cervico-vaginal branches to prevent non-target embolization. |
| What is the goal of treatment? | Slow flow or near stasis in the uterine artery. The goal is not to cause complete stasis or occlude the entire artery. |
| Which uterine arteries are treated? | Bilateral uterine arteries are embolized in order to achieve ischemia and infarction of uterine fibroids. Unilateral uterine artery treatment is likely to result in clinical failure because the blood supply to the uterus has a variety of collateral pathways. |
| When should aortography for ovarian arterial supply be performed? | Disproportionately small uterine arteries |
| | Spasm of the uterine artery, requiring different approach |
| | Non-perfused tissue on uterine angiography |
| | Repeat embolization procedures |
| What are expected MRI findings post fibroid embolization? | T1 signal intensity should increase relative to the myometrium due to increased methemoglobin from coagulative necrosis. There should be no internal enhancement. There should also be decreased size and T2 signal intensity. With the onset of liquefaction, T2 signal intensity will increase. |

## Complications

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| What are some methods of reducing post-UAE pain? | Pretreatment with nonsteroidal anti-inflammatory medications several days before |
| | Intra-procedural superior hypogastric nerve block |
| | Intraarterial lidocaine or Toradol injection |
| | Post-procedure anti-inflammatory medications and analgesics like a PCA pump |
| What should be considered in a post-UAE patient presenting with inflammatory peritonitis? | Pedunculated fibroid detaching from the uterus and falling into the pelvis |
| | Uterine infection/perforation/abscess formation |
| What should be considered in a post-UAE patient presenting with persistent vaginal discharge, tissue passage, and/or menstrual cramping? | Fibroid passage through the cervical os. |
| Which type of fibroid is most at risk for fibroid passage? | Pedunculated large submucosal fibroid. Most will pass uneventfully, though there is risk of cervical obstruction and infection, potentially requiring surgery. |
| How is fibroid passage managed? | Observation +/− antibiotics |
| | Dilation and curettage |
| | Hysteroscopic resection |
| | Manual extraction |
| | Hysterectomy |

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| Which subtype of fibroid has the potential risk of detachment from the uterus following infarction? | Pedunculated subserosal fibroid, especially with stalk diameter <2 cm. |
| What is post-embolization syndrome? | Clinical symptoms including low grade fever, nausea, malaise, and loss of appetite. |
| What is the treatment for post-embolization syndrome? | Supportive management including pain management and fluids. |
| What are the 2 most common complications of UFE? | Permanent amenorrhea; 1–5% of women go into early menopause, which is more common in women older than 45 years old<br>Prolonged vaginal discharge |
| What is the effect of UAE on fertility? | Studies have not been clear as to the risk of infertility after UFE, though; many patients have gone on to have normal pregnancies. |

## Landmark Research

Moss, JG et al. Uterine-artery embolization versus surgery for symptomatic uterine fibroids. NEJM. 2007; 356:360–370.

- Randomized, multi-center study that compared the efficacy and safety of UAE to standard surgical methods for treatment of symptomatic fibroids.
- UFE is less painful at 24 hours with shorter hospital stays and quicker return to work.
- No difference in quality of life scores at 12 months.
- No difference in adverse events.
- UFE more likely to need re-intervention.

Hehenkamp, W et al. Uterine Artery Embolization vs Hysterectomy in the Treatment of Symptomatic Uterine Fibroids (EMMY Trial): Peri- and Postprocedural Results

From a Randomized Controlled Trial. American Journal of Obstetrics and Gynecology. 2005 Nov;193(5):1618–29.

- Randomized controlled trial to evaluate the safety or UAE compared to hysterectomy.
- UAE is similar to hysterectomy with a lower major complication rate and with a reduced length of hospital stay.
- Higher readmission rates after UAE.

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- To assess long-term clinical outcomes of UAE across a wide variety of factors including long-term symptom control, patient satisfaction, rates of recurrence and need for re-intervention
- UAE results in a durable improvement in quality of life.

## Common Questions

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| What is the natural history of fibroids? | Involution following menopause. |
| When should leiomyosarcoma be considered in postmenopausal women? | Rapid fibroid enlargement and/or abnormal enhancement. |
| What are other treatment options for fibroids and adenomyosis that should be discussed with the patient? | Medical therapy |
| | Conservative surgery |
| | Hysterectomy |
| | High Intensity Focused Ultrasound |

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| How does treating from the uterine artery cause fibroid infarction without infracting the normal uterus? | Fibroids have a more robust vascular supply compared to normal myometrial tissue and this allows normal myometrial tissue to remain viable and not become infarcted. |

# Chapter 42
# Prostate Artery Embolization

**Marco Ertreo, Rakesh Ahuja, and Keith Pereira**

## Evaluating the Patient

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| What are the symptoms of BPH (benign prostate hypertrophy)? | Though a predominance of voiding symptoms are reported, both storage and voiding symptoms are experienced and include increased frequency of urination, nocturia, urgency, hesitancy, and weak urine stream (known as LUTS, "lower urinary tract symptoms") |
| What are storage and voiding symptoms? | Storage: urgency, frequency, nocturia, incontinence, bladder sensation<br><br>Voiding: slow stream, intermittent stream, hesitancy, strain, dribble, dysuria |

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| How can BPH be differentiated clinically from overactive bladder (OAB)? | OAB typically presents as urgency with or without urgency and incontinence. |
| | Storage symptoms predominate as compared to BPH, in which voiding symptoms predominate. |
| | OAB: involuntary detrusor contraction during filling allows for detection during cystourethrogram. |
| What specialty does the interventional radiologist closely work with for management of these patients? | Urology. |
| How are LUTS quantified? | Using the American Urological Association urinary symptom score or the International Prostate Symptom Score (IPSS). Both utilize the same scale and questions, but the IPSS includes an additional question on disease specific quality of life. The scores assign a severity score of 0–5 in the categories of incomplete emptying, frequency, intermittency, urgency, weak stream, straining and nocturia. It is an eight-question (seven questions on symptoms and one question on quality of life) used to screen for, rapidly diagnose, track the symptoms of, and suggest management of the symptoms of BPH. The total score ranges from mild (0–7) to severe (20–35). |

| IPSS questionnaire | | | | | | |
|---|---|---|---|---|---|---|
| In the past month | Not at all | Less than 1 in 5 times | Less than half the time | About half the time | More than half the time | Almost always |
| Incomplete emptying (how often have you had the sensation of not emptying your bladder?) | 0 | 1 | 2 | 3 | 4 | 5 |
| Frequency (how often do you have to urinate less than every 2 hours?) | 0 | 1 | 2 | 3 | 4 | 5 |
| Intermittency (how often have you found you stopped and started again several times when you urinated?) | 0 | 1 | 2 | 3 | 4 | 5 |

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| Urgency (how often have you found it difficult to postpone urination?) | 0 | 1 | 2 | 3 | 4 | 5 |
| Weak stream (how often have you had a weak urinary stream?) | 0 | 1 | 2 | 3 | 4 | 5 |
| Straining (how often have you had to strain to start urination?) | 0 | 1 | 2 | 3 | 4 | 5 |
| Nocturia (how many times did you typically get up at night to urinate?) | None | 1 time | 2 times | 3 times | 4 times | 5 times |
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Quality of life: how would you feel about living for the rest of your life with your urinary condition? | | | | | | |
| Delighted | Pleased | Mostly satisfied | Mixed feelings | Mostly dissatisfied | Unhappy | Terrible |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |

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| How is BPH diagnosed? | Digital rectal exam and correlation with symptoms. |
| What laboratory results should be obtained? | PSA, coagulation profile, urinary analysis. |
| What other clinical metrics should be considered during patient evaluation? | Quality of life (QoL) scale, International Index of Erectile Function (IIEF). |
| When should urodynamic studies be performed? | The American Urological Association recommends performing urodynamic studies in men with LUTS when invasive, potentially morbid or irreversible treatments are considered. |
| What information can be obtained from urodynamic studies? | Measures of uroflowmetry include urinary peak flow rate (Qmax), average flow rate, voided volume, flow time, time to maximum flow, and postvoid residual (PVR). A healthy adult male has a Qmax of approximately 25 mL/s. This decreases in patients with BPH and is typically found to be below 12–15 mL/s. Patients with BPH also have an elevated PVR above 200 mL. |
| What imaging should be available? | Prostate MRI and Pelvic CTA or MRA. |

## High Yield History

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| What other conditions can simulate BPH-related LUTS? | Neuropathic bladder (such as neurogenic bladder disorder, multiple sclerosis and Parkinson's disease), outflow obstruction (bladder and prostate cancer), diuresis (due to congestive heart failure), prostatitis. |

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| Can medications contribute to worsening LUTS? | Yes, particularly antidepressants, diuretics, bronchodilators, and antihistamines. When evaluating a patient, you should first consider changing the medications which may be causing LUTS before planning additional therapies. |
| Is PAE indicated in patients with prostate cancer? | No, though early research is occurring for this indication. |

## Indications/Contraindications

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| What is the current main indication for prostate artery embolization (PAE)? | Treatment of lifestyle limiting LUTS symptoms. According to most recent guidelines, PAE should be contemplated only for highly symptomatic patients with BPH who are not responsive to medical treatment and are unsuitable for surgery or refuse surgery. |
| What are secondary indications for PAE? | Severe prostatic hemorrhage secondary to prostate cancer, biopsy, or BPH. Embolization for prostatic hemorrhage was the original primary indication for PAE. |
| How does PAE work? | Embolization of arteries supplying the prostate causes prostatic infarction and reduction of gland size. |
| Who should undergo PAE? | IPSS > 18, moderate-to-severe LUTS for at least 6 months refractory to medical therapy, prostate volume > 30 $cm^3$. |
| What are contraindications? | Prostate volume < 30$cm^3$, malignancy, active UTI, tortuosity and/or atherosclerosis of iliac prostatic arteries, coagulopathy, neurologic conditions affecting bladder tone, bladder diverticula, or calculi. PAE efficacy has not been demonstrated in other causes of LUTS, such as prostate cancer, prostatitis, or urethral strictures. |

## Relevant Anatomy

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| What is benign prostatic hyperplasia (BPH)? | Proliferation of smooth muscle and epithelial cells in the transitional zone of the prostate, which surrounds the urethra. |
| How many lobes does the prostate have? | Anterior, median, lateral (left and right), and posterior lobes. |
| What is the importance of the median lobe? | An enlarged median lobe can grow into the bladder causing intravesical protrusion and bladder outlet obstruction. Patients with LUTS caused by median lobe hypertrophy have been shown to be less responsive to medical therapies and more difficult to treat with interventions. |
| How many zones is the prostate divided in? | Three; central, transitional, and peripheral. |
| What zone is usually responsible for BPH and why? | Transitional zone, because it surrounds the urethra. |
| In which zone does cancer usually arise? | Peripheral zone; 70–80% of cancers arise in this zone. |
| What vessel supplies the prostate? | Prostatic artery (PA), which has two main branches: the anterolateral branch, which supplies the central gland, and the posterolateral branch, which supplies the peripheral gland and capsule. The branches may arise together from a common trunk or separately. For successful PAE, both branches must be embolized given the significant anastomoses between the two branches. |

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| Where does the PA arise from? | The PA typically arises from the inferior vesical artery (IVA), a branch of the anterior division of the ipsilateral internal iliac artery (IIA). The internal iliac artery is the main artery that supplies pelvic structures and there is high variability in regards to PA origin. |
| What are the 5 most common anatomical variants of PA origin? | Type 1 – The IVA arises from the anterior division of the IIA in a common trunk with the superior vesical artery. |
| | Type 2 – The IVA arises separately and inferiorly from the superior vesical artery. |
| | Type 3 – The IVA arises from the obturator artery. |
| | Type 4 – The IVA arises from the internal pudendal artery. |
| | Type 5 – All other less common origins. |
| | Type 1 and 4 are most common variants. |
| What acronym can be used to remember the branches of the anterior division of the internal iliac artery? | PROVISO, which stands for internal Pudendal, middle Rectal, Obturator, Vesical Inferior and Superior in caudo-cranial direction; the last O stands for Oblique, as in ipsilateral oblique view, which is the projection in which the mnemonic is to be used. |

## Relevant Materials

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| What particles are used for embolization? | Trisacryl gelatin microspheres (Embosphere®) or polyvinyl alcohol particles (PVA), size ranging between 100 and 500 μm. Dimension of the particles used during PAE vary in the published experience from 50 to 300 to 500 μm. Many studies have been performed and have suggested that larger particles tend to perform slightly better, but studies are heterogeneous, and there is still not enough data to conclude standard particle size. |
| What do smaller particles increase risk of? | Nontarget embolization. |
| What kind of catheter is used? | Microcatheter. |

## General Step by Step

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| Are preprocedural antibiotics administered? | Operator dependent. Often, a quinolone (levofloxacin 750 mg twice daily) is administered for 2 days prior to the procedure and for 7–10 days following it. |
| What other pre-procedure medications should be administered? | Pre-procedural medication regimens may vary, though including oral diclofenac 100 mg/d and famotidine 20 mg twice daily for 2 days before the procedure and the morning of the procedure. |

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| Why do many IRs place a bladder catheter (iodinated contrast medium (20–30%) and saline solution in the balloon) during the procedure? | This is helpful as an anatomical landmark (delineates prostate location, internal iliac artery branches, and other structures). |
| What kind of access is used? | Femoral, usually unilateral (right). Alternatively, radial access can be used (usually left). |
| Are the prostatic arteries on each side embolized? | Yes. Bilateral PAE is generally accepted as the best choice in terms of clinical results compared to unilateral embolization, due to the deep connections that exist between the PAs. Bilateral PAE is feasible from a single-sided approach, due to intraprostatic anastomoses and the possibility to cross from one side to the other one. This technique may be considered in patients with an occluded internal iliac artery on one side. |
| Where is the catheter initially placed after access? | Anterior division of the internal iliac artery. |
| What are the best projections to identify the prostatic artery anatomy after appropriate catheter placement? | Anterior oblique (25°–55°, usually 35°) and caudal-cranial (10°–20°, usually 10°) projections. |

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| What technique can facilitate microcatheter navigation? | Nitroglycerine or isosorbide mononitrate is a vasodilator used to prevent vasospasm and to increase artery size to facilitate microcatheter navigation and distal positioning. When the microcatheter is advanced beyond the collateral branches, the embolization can start. |
| What is cone beam CT (CBCT) and why would it be useful during PAE? | CBCTis an imaging technique that utilizes the flat panel imaging detectors of the C-arm in the angiographic suite to obtain volumetric data and, ultimately, deliver cross-sectional images similar to those acquired with a traditional CT. Images are acquired following contrast injection with the catheter tip in the target vessel. CBCT delivers better soft tissue contrast and three-dimensional information compared to digital subtraction angiography, helping delineate vascular territories and confidently identify the prostatic arteries, decreasing the risk of non-target embolization. |
| When is the injection of embolic material stopped? | At "near stasis" or complete stasis in the prostatic arteries. When reaching stasis, some operators opt to advanace the microcatheter into the prostatic parenchymal branches for an intraprostatic embolization. |

## Complications

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| What is post-embolization syndrome? | Clinical symptoms including low-grade fever, nausea, malaise, and loss of appetite caused by an inflammatory response (cytokine release). |

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| What is the management of post-embolization syndrome? | Supportive; pain management and fluids. |
| What are some of the most common complications after PAE? | PAE complications can be divided into minor and major. Minor: temporary urinary frequency, hematospermia, urinary tract infections and balanitis, hematuria, dysuria, rectal bleeding, acute urinary retention, and inguinal hematoma. Major: Bbladder ischemia (reported). |
| What is the treatment? | Anti-inflammatory medications, pain management. |
| What are potential sites of non-target embolization? | Bladder, rectum, and seminal vesicles. |
| What is a severe but rare complication? | Bladder wall necrosis. |

## Landmark Research

Pisco JM, Bilhim T, Pinheiro LC, et al. Medium- and Long-Term Outcome of Prostate Artery Embolization for Patients with Benign Prostatic Hyperplasia: Results in 630 Patients. J Vasc Interv Radiol. 2016

- Most clinical failures occurred within 12 months from the procedure and most of these were within the first month.
- Clinical success, in terms of improvement of IPSS, quality of life questionnaire (QOL), and no need for medical therapy following PAE, was seen in 81.9% and 76.3% of patients at medium (1–3 years) and long term (>3 years) follow-up, respectively.

- Overall, morbidity was low and patients did not experience sexual dysfunction or urinary incontinence.

Russo GI, Kurbatov D, Sansalone S, Lepetukhin A, Dubsky S, Sitkin I, Salamone C, Fiorino L, Rozhivanov R, Cimino S, Morgia G. Prostatic arterial embolization vs open prostatectomy: a 1-year matched-pair analysis of functional outcomes and morbidities. Urology 2015

- PAE patients had a higher risk of persistent symptoms and lower peak flow at 1 year compared to open prostatectomy.
- PAE patients experienced significantly lower complication rates.

Gao Y, Huang Y, Zhang R, Yang Y, Zhang Q, Hou M, et al. Benign Prostatic Hyperplasia: Prostatic Arterial Embolization versus Transurethral Resection of the Prostate—A Prospective, Randomized, and Controlled Clinical Trial. Radiology 2014

- PAE is technically more challenging to perform compared to TURP: the success rates for PAE and TURP were 94.7% and 100%, respectively.
- Fewer PAE patients were admitted to the hospital following the procedure compared to TURP (48.1% versus 100%) and the average hospital stay was shorter following PAE (2.9+/−1.6 days versus 4.8+/−1.8 days).
- Symptomatic relief from PAE occurs less rapidly compared to TURP, but at 24 months improvement is similar to patients that underwent TURP.
- The PAE group showed more adverse events and complications, although technical and clinical failures were considered adverse events in this study.

## Common Questions

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| What is the current first line of treatment for LUTS? | Medical treatment, for patients with mild to moderate LUTS, with α-blockers (such as tamsulosin or doxazosine) and 5α-reductase inhibitors (finasteride or dutasteride). |
| What is current gold standard treatment for moderate-to-severe LUTS from BPH? | Transurethral resection of the prostate (TURP). |
| Who is a candidate for TURP? | Patients with medication refractory LUTS and mild-to-moderate-sized prostate. |
| What is the current surgical option for patients with large prostates? | Open, laparoscopic, or robotic-assisted prostatectomy. |
| What are potential complications with TURP? | Electrolyte imbalance (due to saline infusion, also known as TURP syndrome), acute urinary retention, urinary tract infection, urethral stricture, retrograde ejaculation, erectile dysfunction, urinary incontinence, and, less common, bleeding requiring transfusion. |

## Further Reading

AUA urodynamics guidelines. https://www.auanet.org/guidelines/urodynamics-guideline.

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# Part VII
# Neuro

# Chapter 43
# Stroke

**Sarah E. Pepley and Agnieszka Solberg**

## Evaluating Patient

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| How does a transient ischemic attack (TIA) differ from a stroke? | Since 2009, the definitions of stroke and TIA are no longer based on the duration of symptoms but on imaging findings. The definition of stroke is "an infarction of central nervous system (CNS) tissue." A TIA is a "transient episode of neurological dysfunction caused by focal brain, spinal cord, or retinal ischemia without infarction." |
| Name the main classifications of stroke and their relative incidence. | The main classifications are ischemic stroke and hemorrhagic stroke. Ischemic strokes are more common with an incidence of 87%; hemorrhagic stroke incidence is 13%. Hemorrhagic stroke can be divided into intracerebral hemorrhage (ICH ~ 10%) and subarachnoid hemorrhage (ICH ~ 3%). |
| What are ischemic stroke subtypes and their relative incidence? | |

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| Cardioembolic | 27% |
| Large artery atherosclerosis | 13% |
| Small vessel disease | 23% |
| Other known causes | 22% |
| Unknown causes | 35% |

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| Describe the pathophysiology of an ischemic stroke. | Embolic strokes occur when pieces of plaque, thrombus, fat, or other materials travel to become lodged in brain CNS vasculature, decreasing blood supply distal to the site of occlusion. Atrial fibrillation, endocarditis, and long bone fractures are risk factors for embolic strokes.<br><br>Large vessel disease, particularly carotid artery atherosclerosis, can also lead to cerebral hypoperfusion or an embolic ischemic stroke. Plaque rupture may also occur, resulting in watershed infarcts when collateral circulation via the Circle of Willis (COW) is unable to compensate (often seen in variant incomplete Circle of Willis). Watershed zones in the brain are site of collateral circulation and may be susceptible to embolic disease; cortical watersheds occur between the MCA and ACA (anterior), as well as the MCA and PCA (posterior).<br><br>Small vessel disease of the smaller penetrating arteries may cause ischemic strokes, often due to thickening of the arterial media or parent artery intimal plaques at the origin of penetrating artery. |

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| What is the main clinical patient assessment tool used in the evaluation of acute stroke? | The main assessment is the NIHSS Score – National Institute of Health Stroke Severity Score. |
| | The NIHSS score describes the physical limitations caused by the acute stroke. Neurologic impairment is classified based on its severity and extent. The scale is between 0 and 42 with higher scores (≥21) indicating a severe stroke. |
| What is the best primary imaging study to order for suspected stroke with onset of fewer than 6 hours? | CT of head without IV contrast is the best primary imaging study. CT is widely available and can quickly rule out intracerebral hemorrhage and stroke mimics (neoplasm, arteriovenous malformation, etc.). |
| | According to the AHA/ASA guidelines, door-to-imaging time should be within 25 minutes, while door-to-interpretation time should be within 45 minutes. |
| What imaging study should you order if there is suspicion for large vessel occlusion (LVO)? | CTA of the head and neck. |
| What additional imaging studies are ordered if the stroke onset is between 6 and 24 hours? | CT perfusion or MR perfusion. A sign of subacute to chronic occlusion is increased collateral circulation in the infarcted territory. |
| What non-imaging tests should be ordered if suspecting stroke and why? | Glucose – because hypoglycemia and hyperglycemia can mimic a stroke. |

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| | Coagulation parameters (platelets, PT/INR, aPTT) to assess coagulation and screen for contraindications to thrombolytics. |
| | CBC and electrolytes/BUN/Cr may also be checked – however if CTA needs to be performed for an acute stroke with suspicion for large vessel occlusion (LVO), creatinine is not a prerequisite in patients without the history of renal impairment if it will delay therapy. |
| | Troponin – baseline. |
| | ECG – baseline. |
| | With the exception of blood glucose and INR ≥2, none of these tests should delay the initiation of IV alteplase (tPA). |

## High Yield History

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| What is the difference between modifiable and non-modifiable risk factors for ischemic stroke? | Non-modifiable |
| | Family history |
| | Race |
| | Genetics |
| | Age/gender |
| | Previous history of stroke or TIA |
| | Modifiable |
| | Hypertension |

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| | Coronary artery disease |
| | Carotid artery disease |
| | A-fib or atrial flutter |
| | Diabetes mellitus |
| | Obesity |
| What are typical symptoms of acute ischemic stroke? | Typically, there is sudden onset of weakness, speech or visual disturbance, confusion, headache, or sensation of dizziness or imbalance. |
| | Left hemispheric stroke: |
| | Left gaze preference |
| | Right visual field defect |
| | Right hemiparesis |
| | Right sensory loss |
| | Right hemispheric stroke: |
| | Right gaze preference |
| | Left visual field defect |
| | Left hemiparesis |
| | Left sensory loss and inattention |
| | Cerebellar stroke: |
| | Truncal/gait ataxia |
| | Limb ataxia |
| | Neck stiffness |
| | Brainstem (posterior circulation) stroke: |
| | Nausea and vomiting |
| | Diplopia, deconjugate gaze, gaze palsy |
| | Dysarthria, dysphagia |
| | Vertigo, tinnitus |

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| | Hemiplegia, quadriplegia |
| | Hemiparesis |
| | Decreased level of consciousness |
| | Hiccups and abnormal respirations |
| | Hemorrhagic |
| | Focal neurological deficits corresponding to affected region |
| | Nausea and vomiting |
| | Headache |
| | Neck pain |
| | Light intolerance |
| | Decreased level of consciousness |
| What are risk factors for intracranial hemorrhage vs subarachnoid hemorrhage? | Intracranial hemorrhage: |
| | Hypertension |
| | Alcohol |
| | Diabetes mellitus |
| | High cholesterol |
| | Tobacco |
| | Diet |
| | Inactivity |
| | Obesity |
| | Substance abuse |
| | Caffeine |
| | Subarachnoid hemorrhage: |
| | Hypertension |

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| | Tobacco |
| | Alcohol |
| | Substance abuse |
| | Family history |
| | Age >40 |
| | Female gender |
| | Arteriovenous malformation |
| | Polycystic kidney disease, connective tissue disorder, and neurofibromatosis |
| What is the modified Rankin scale? | The modified Rankin scale is a scale from 0 to 6 to assess degree to which stroke has impacted a patient's overall function and independence performing activities of daily living. The modified Rankin scale is often used as an outcome measure in clinical trials. |

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| 0 | No symptoms |
| 1 | No disability despite symptoms |
| 2 | Slight disability; needs only minimum assistance to care for personal affairs |
| 3 | Moderate disability; walks unassisted |
| 4 | Moderately severe disability; requires help walking |
| 5 | Severe disability; bedridden |
| 6 | Death |

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| What are common neuroimaging findings on noncontrast head CT in acute ischemic stroke? | Cortical-subcortical hypoattenuation in a vascular territory estimates the area of the infarct but has low sensitivity in first 24 hours. Signs include: subtle hypoattenuation, loss of gray/white matter differentiation in basal ganglia, cortical sulcal effacement, insular ribbon loss, and hyperattenuation of a large vessel (hyperdense MCA sign or dot sign). |

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| What is the ASPECTS score? | The Alberta Stroke Program Early CT Score standardizes the reporting of early ischemic signs with superb interobserver reliability. A normal CT scan receives 10 points. An ASPECTS score of ≤7 points highly correlates with negative functional outcome. |

How are acute ischemic strokes classified by time?

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| Early hyperacute [oxyhemoglobin] | 0–6 hours old (T1: isointense; T2: bright) |
| Late hyperacute (or acute) [deoxyhemoglobin] | 6–24 hours old (T1: isointense; T2: dark) |
| Acute (or early subacute) [methemoglobin] | 24 hours to 7 days old (T1: bright; T2: dark) |
| Subacute (or late subacute) [methemoglobin] | 1–3 weeks old (T1: bright; T2: bright) |
| Chronic [hemosiderin] | > 3 weeks old (T1: dark; T2: dark) |

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| What is the penumbra in neuroimaging? | Penumbra is "at risk" tissue surrounding a central core of irreversible damage. This peripheral region of stunned tissue receives blood supply via a collateral arterial network from uninjured tissue and/or leptomeninges. These areas are most likely to benefit from reperfusion. Perfusion imaging identifies penumbra as increased mean transit time (MTT) with decreased cerebral blood flow (CBF) and normal or mildly increased cerebral blood volume (CBV). The mild increase in CBV occurs secondary to autoregulation. The infarct core demonstrates a markedly decreased CBF and CBV. The penumbra can be estimated by CBF-CBV and is typically found to be 11–20 mL/100 mg/min (normal >50 mL/100 mg/min). Software is available to automatically quantitate penumbra and infarct core size to aid the interventionalist in clinical decision making. |

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| Does every stroke patient require intubation or supplemental oxygen? | No, this is not the case. Patients with decreased consciousness or bulbar dysfunction resulting in airway compromise should receive airway and ventilatory support. Supplemental oxygen is recommended if required to maintain oxygen saturation >94%. Hyperbaric oxygen is not recommended with the exception of a cerebral air embolism. |

## Indications/Contraindications

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| What is the time window for IV alteplase infusion in stroke? | 3 hours |
| | 4.5 hours for a more selective group of acute stroke patients (based on ECASS III exclusion criteria) |
| How is t-PA prepared and administered? | The dose of t-PA is 0.9 mg/kg (max dose 90 mg) infused over 60 minutes. |
| | 10% of this dose is administered as a bolus that is infused over 1 minute. |
| | The dose requires reconstitution and comes as a bolus in a syringe. |
| | A 30-minute post t-PA NIHSS should be obtained. |
| | The patient should be maintained NPO until a speech and language evaluation has been performed. |
| | Avoid dextrose IV fluids (mitigates lactic acidosis risk). |
| | Head CT should be obtained 24 hours after administration. |

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| What are the only tests absolutely required prior to alteplase administration? | Glucose and non-contrast head CT. |
| | It is not necessary to obtain PT, INR, aPTT, or platelets if there is no suspicion of underlying coagulopathy. |
| | Non-contrast CT of the head should be obtained within 20 minutes of patient arrival. |
| What are absolute contraindications to IV alteplase? | Wake-up stroke or time of symptom onset >4.5 hours |
| | Acute intracranial hemorrhage on non-contrast CT |
| | Ischemic stroke or severe head trauma within 3 months |
| | Intracranial/spinal surgery within 3 months |
| | History of intracranial hemorrhage |
| | Current structural GI malignancy or recent GI bleed within 21 days of stroke |
| | Coagulopathy – platelets < 100,000/mm3, INR > 1.7, aPTT > 40s, PT > 15 s |
| | Treatment dose of low-molecular-weight-heparin in past 24 hours; contraindication does NOT apply to prophylactic doses |
| | Treatment with direct thrombin inhibitors or direct factor Xa inhibitors – unless coagulation studies are normal and it has been > 48 hours since last dose in the setting of normal renal function |

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| | Glycoprotein IIb/IIIa receptor inhibitors – cannot be administered concurrently |
| | Infective endocarditis |
| | Aortic arch dissection |
| | Intra-axial intracranial neoplasm |
| What are the indications for mechanical thrombectomy < 6 hours of symptom onset? | ≥ 18 years old |
| | Minimal prestroke disability (mRS 0–1) |
| | Occlusion of ICA or proximal MCA (M1) |
| | NIHSS score ≥ 6 |
| | Reassuring noncontrast head CT (ASPECTS score ≥ 6) |
| | Can be treated within 6 hours of last known normal |
| | It is also reasonable to treat M2 and M3 MCA segments, ACA, vertebral artery, basilar artery, and the posterior cerebral artery. It is reasonable to consider candidates with higher mRS scores, and lower ASPECTS and NIHSS scores; however, these are IIb recommendations. |
| What are the indications for mechanical thrombectomy 6–16 hours after symptom onset? | The patient should present with an LVO in the anterior circulation. In addition, the patient needs to meet additional DAWN or DEFUSE 3 eligibility criteria. |

| | DAWN trial | | | DEFUSE 3 trial |
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| NIHSS score | ≥ 10 | | | ≥ 6 |
| LVO location | ICA, M1 | | | ICA, M1 |
| Thrombectomy time window | 6–24 hours | | | 6–16 hours |
| Core infarct size | *Group A*<br>Age ≥ 80<br>core<br>< 21 mL | *Group B*<br>Age < 80<br>NIHSS<br>≥ 10 core<br>< 31 mL | *Group C*<br>Age < 80<br>NIHSS<br>≥ 20 core<br>< 51 mL | CTP/MRP<br>core < 70 mL<br>Penumbra/core<br>≥ 1.8 mL |

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| What are the indications for mechanical thrombectomy 16–24 hours after symptom onset? | The patient should present with an LVO in the anterior circulation. In addition, the patient needs to meet additional DAWN eligibility criteria. |
| Is there a maximum age limit for mechanical thrombectomy? | No, there is no maximum age limit. Mortality benefit has been shown in patients > 80 years old who undergo thrombectomy, which is an age group in which mechanical thrombectomy has traditionally been controversial. The patient selection criteria for mechanical thrombectomy, however, do change based on the patient's age if the patient presents 6–24 hours since last known well or with wake-up stroke. |
| What are absolute contraindications for mechanical thrombectomy? | Absolute contraindications include evidence of hemorrhagic conversion, midline shift, or expected "futility" of treatment (core infarct > 70 mL on DWI, < 20% penumbra on perfusion study, or ASPECTS score < 6 on noncontrast CT). |

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| True/false: If there is suspicion for large vessel occlusion and a patient is a candidate for mechanical thrombectomy, he/she should not be considered for IV alteplase. | This is false. Patients eligible for intravenous alteplase should receive the treatment even if endovascular procedures are being considered. IV alteplase should not delayed. Patients who receive IV alteplase are still eligible for endovascular treatments. |
| True/false: A patient received IV alteplase and is being considered for mechanical thrombectomy. Is it reasonable to observe the patient for clinical response prior to mechanical thrombectomy? | This is false. If a patient who received IV alteplase is being considered for mechanical thrombectomy, observation to assess for clinical response should not be performed. The patient should be rushed to the interventional suite. |
| What are typical indications for the administration of intraarterial t-PA? | Primary intraarterial thrombolysis<br>Severe disabling neurological deficit<br>Contraindication to IV thrombolysis (e.g., recent surgery), 3–6 hours from symptoms onset<br>Dense artery sign on the CT head scan<br>Rescue thrombolysis<br>Severe disabling neurological deficit<br>No improvement with IV thrombolysis<br>No recanalization or early reocclusion after IV thrombolysis |

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| | Brainstem stroke<br>Treatment can be delivered within 12 hours of symptom onset<br>Occlusion of basilar artery documented on 4-vessel angiography<br>Eligible even if consciousness impaired or patient ventilated |

## Relevant Anatomy

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| What is the preferred access site for mechanical thrombectomy in ischemic stroke? | Common femoral artery, although radial artery, brachial artery, or infrequently carotid artery access may be used. |
| Why is the shape of the aortic arch important? | The shape and tortuosity of the aortic arch may affect the arterial access for the patient (groin vs. other) and selection of the catheter.<br>The elongation of the arch occurs with increasing age and makes selective catheterization more difficult. Arch types are determined by comparing the distance (D) between the brachiocephalic origin to the most cephalad margin of the arch and the diameter of the brachiocephalic trunk or left common carotid artery. Type 3 arches are steepest and most difficult to navigate:<br>1 = D < 1 reference vessel diameter<br>2 = D is between1 and 2 reference vessel diameters<br>3 = D > 2 vessel diameters |

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| What major blood vessels compose the Circle of Willis? Which compose the anterior versus posterior circulation? | Anterior circulation: anterior communicating arteries, anterior cerebral arteries, internal carotid arteries (middle cerebral arteries are not considered part of the Circle of Willis)<br><br>Posterior circulation: posterior communicating arteries, posterior cerebral arteries |
| Describe the pathway of blood flow from the aortic arch to the posterior circulation. | Aortic arch --> innominate artery (right side only) --> R and L subclavian arteries --> R and L vertebral arteries --> basilar artery --> bifurcation to form R and L posterior cerebral arteries. |

## Relevant Materials

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| What is the typical dose of intraarterial alteplase? | Intra-arterial (IA) alteplase total doses range from 10 to 20 mg. |
| What types of devices are available for mechanical thrombectomy in stroke? | Clot retrievers (Catch device, MERCI retriever, Phenox clot retriever), aspiration devices (Penumbra ACE and Medtronic Riptide), and stent retriever devices (Medtronic Solitaire, Stryker Trevo, Penumbra 3D, Cerenovus EmboTrap II). |
| What is the Solumbra technique? | The Solumbra technique is the use of a stent retriever with an adjacent large bore aspiration catheter to minimize the chance of fragmentation and distal embolization. |

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| What is the ADAPT technique? | ADAPT stands for A Direct Aspiration first Pass Technique. It utilizes aspiration as the first approach to revascularize the occluded vessel. If aspiration fails, then an aspiration catheter is used with a stent retriever to obtain revascularization. |
| What factors must be considered when preparing for endovascular coil treatment (ECT) of aneurysms? | Size and shape of aneurysm, relationship of aneurysm to cranial nerves, neck-to-dome ratio of aneurysm, perforating branches arising from aneurysm. |

## General Step by Step

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| True/false: Always obtain imaging of the brain before initiating therapy for acute ischemic stroke. | True, in order to rule out active bleeding/hemorrhage. |
| What catheters are typically used to select aortic branches? | Catheters include the Headhunter, Sidewinder, Simmons, Newton, Osborn, Bentson, or Mani catheters, as they allow the operator to maneuver the sharp turns of the arch vessels. Other useful catheters include the Berenstein and vertebral catheter. The choice of catheter depends on the operator and arch shape/tortuosity. |
| Describe an example of a typical set-up for a stroke intervention via groin access (ADAPT technique). | Sheath – often an 8 French short (11 cm) sheath will be used. |

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| | Neurosheath – Neuron Max 088 (6F) is usually navigated into the petrous ICA for proximal support. |
| | Largest caliber aspiration catheter that the vessel can accommodate is selected (Commonly ACE 068 or JET 7) and advanced with the aid of a microcatheter (3Max) and microwire (Fathom). The tri-axial system allows for navigation past the carotid siphon tortuosity, especially the ophthalmic bend. The ACE must be advanced to the thrombus. |
| | Once the system is advanced to the thrombus, the microcatheter and microwire are removed. |
| | Aspiration is begun via the ACE or JET catheter. |
| | When the aspiration catheter is being removed, aspiration is applied to the sideport of the Neuron Max to prevent dislodging of the thrombus. |
| | Some operators use a catheter with a balloon to occlude forward flow in the ICA during the thrombectomy. |
| What are the steps of stent retrieval mechanical thrombectomy after the clotted vessel is identified and selected? | Similar to ADAPT - 8F sheath, NeuronMax, ACE 68. |
| | Velocity microcatheter is usually used with the microwire (Transcend). The wire and microcatheter must be navigated past the thrombus. |

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| | Wire is removed and stent retriever is advanced through the microcatheter.<br><br>Microcatheter is pulled back to deploy the stent retriever.<br><br>Depending on type of stent retriever, it is either pulled back into the microcatheter or resheathed. |
| What are some reasons to switch from ADAPT to Solumbra technique? | Unable to navigate ACE60/68 past ophthalmic artery – common reasons include:<br><br>Proximal vascular tortuosity<br><br>Large aneurysm proximal to site of occlusion<br><br>Tall patient<br><br>Aspiration does not work. Different centers will try a different number of ADAPT passes to achieve recanalization. Some may try ADAPT up to 4 or 5 times, and some try only one time before switching to Solumbra. The goal is to re-perfuse to TICI 2b/3 as quickly as possible. |
| What is the minimum time required to allow the clot to lyse after administering thrombolytic agents? | 5 minutes. |
| What is the ideal blood pressure to maintain a stroke patient before reperfusion? | Blood pressure ≤180/105 mm Hg during and after the procedure. |

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| What is the modified thrombolysis in cerebral infarction score? (mTICI)? | This is a consensus scale (0–3), which measures successful reperfusion following treatment. Scores of 2b and 3 are considered successful reperfusion.<br><br>0: No reperfusion<br><br>1: Flow beyond occlusion, no distal branch reperfusion<br><br>2a: Reperfusion of < 50% downstream target arterial territory<br><br>2b: Reperfusion of > 50% (< 100%) downstream target arterial territory<br><br>3: Complete reperfusion of the downstream target arterial territory, including distal branches with slow flow<br><br>Given a difference in outcomes between 2b and 3, a score of 2c has been recently proposed to identify a subgroup of patients with better outcomes than 2b group. 2c represents near complete perfusion except for a small number of distal cortical emboli. |

## Complications

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| What are the most common complications following mechanical thrombectomy? | Intracerebral hemorrhage (~6%), puncture site complications (5%; for example, groin hematoma), and distal embolization of a new territory (4%). |
| How is symptomatic intracerebral hemorrhage managed if resulting after alteplase administration? | Stop alteplase infusion. |

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| | Laboratory evaluation – CBC, PT (INR), aPTT, fibrinogen, type and cross-match (these may not have been done prior to alteplase administration if there is no history of thrombocytopenia or anticoagulation). |
| | Emergent noncontrast head CT. |
| | Cryoprecipitate 10 U. Additional doses for fibrinogen <200 mg/dL. |
| | Tranexamic acid or ε-aminocaproic acid IV until bleeding is controlled. |
| | Hematology and neurosurgery consultation. |
| | Employ supportive therapy, including airway and blood pressure management, airway management. Steps to decrease intracranial pressure (ICP) should be taken, such as mannitol infusion or craniotomy. Keep in mind temperature and glucose control. |
| What is a feared complication of alteplase administration, and what is the treatment? | Orolingual Angioedema. |
| | To treat: |
| | Maintain airway |
| | Stop alteplase and avoid ACEIs |
| | Administer IV methylprednisolone, diphenhydramine, and ranitidine/famotidine |
| | If there is no improvement, administer epinephrine (0.1%) 0.3 mL subcutaneously or 0.5 mL by nebulizer |

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| | Sometimes Icatibant (selective bradykinin B2 receptor antagonist) can be used<br><br>Supportive care |
| What are examples of device-related complications? | Arterial perforation, arterial dissection, and vasospasm may occur. Arterial perforation is considered one of the most dangerous of these complications due to the high flow nature of the arterial system. If this occurs, glue, coil, or stent grafts may be used to repair the artery. Embolic ischemic stroke in another vascular territory is also a possibility. |
| When is peak time for cerebral vasospasm following subarachnoid hemorrhage (SAH), and what is the standard for prevention of complication? | Cerebral vasospasm following SAH traditionally occurs between days 5 and 15, with the peak time of occurrence at 7–8 days. The FDA has approved Nimodipine for use in treating vasospasm, and data has illustrated this drug's ability to decrease secondary ischemia. |
| Why is decompressive craniotomy useful in some stroke patients? | Patients who suffer a large ischemic stroke affecting >50% of MCA territory are at risk for severe cerebral edema. This cerebral edema can result in extremely high ICP and lead to eventual herniation with resulting brain death; Thus, removing part of the skull allows for brain swelling and accompanying expansion. |

## Landmark Research

What has been shown by the DAWN and DIFFUSE trials?

- Changed stroke guidelines; Patients now eligible for thrombectomy up to 24 hours after last known well

- Captured patients presenting in the 6–24 hours after last known well window
- 35% increase in number of patients achieving functional independence (mRS 0–2)

Why did the IMS III, SYNTHESIS, and MR RESCUE trials not demonstrate a benefit in endovascular treatment over alteplase?

- Primary interventions are outdated technology: IMS III and MR RESCUE – MERCI device; SYNTHESIS – IA-tPA and fragmentation; these techniques are no longer used.
- Most patients did not have LVO in IMS III and SYNTHESIS.
  - IMS III 33% with LVO.
  - SYNTHESIS 34% with LVO.
- Successful recanalization rates were extremely low.

Although IMS III, SYNTHESIS, and MR RESCUE trials did not demonstrate a benefit for endovascular treatment over IV alteplase, what important information did we gain from these trials?

- There is essentially no difference in post-treatment risk profile (intracerebral hemorrhage and death) compared to IV alteplase.

What was the first trial which demonstrated a benefit with endovascular treatment vs. IV alteplase? What was different about this trial compared to its predecessors?

- The first was the MR CLEAN trial, which required confirmation of a large vessel occlusion by CTA. Also, specific measures were taken to minimize selection bias – 100% of stroke centers in the Netherlands participated in the trial.

Which four additional RCTs demonstrated evidence for endovascular intervention after MR CLEAN?

- ESCAPE
- EXTEND-IA

- SWIFT PRIME
- REVASCAT

| | TICI 2b/3 rate | mRS 0–2 at 90 days | Death rate |
|---|---|---|---|
| ESCAPE | 72% | 53% vs. 29% | 10% vs. 19% |
| EXTEND-IA | 86% | 71% vs. 40% | 9% vs. 20% |
| SWIFT PRIME | 88% | 60% vs. 36% | 9% vs. 12% |
| REVASCAT | 66% | 44% vs. 28% | 18% vs. 16% |

What are the main lessons from MR CLEAN, ESCAPE, EXTEND-IA, SWIFT PRIME, and REVASCAT trials?

- Endovascular treatment has been shown to improve clinical outcomes over IV alteplase alone in patients with acute stroke secondary to a proximal large vessel occlusion.
- Endovascular thrombectomy is the only treatment option for patients with LVO and a contraindication to alteplase.
- Careful patient selection and prompt recanalization maximize the likelihood of good patient outcome.

What are the results of the ASTER trial?

- ASTER trial compared ADAPT technique (3 passes then adjunctive therapy) vs. stent retriever with balloon guide catheter.
- No significant differences in characteristics except time from clot contact to TICI 2b/3 was 13 minutes for ADAPT vs. 22 minutes for stent retriever ($p = 0.03$).
- No difference between primary endpoint – mTICI 2b/3 post treatment.
- Trial confirms that ADAPT is safe and effective frontline approach for mechanical thrombectomy.

What is the COMPASS trial?

- It is the US version of ASTER → stent retriever vs. ADAPT. Direct aspiration was not inferior to stent retriever in a randomized controlled trial of first-line treatment in large vessel occlusion, in which functional independence was the primary outcome.

## Common Questions

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| How often should a patient receive neurological checks in the ICU post mechanical thrombectomy? | Every 15 minutes for the first hour, then every 1 hour for the next 24 hours. |
| What kind of follow-up imaging should these patients receive? | Noncontrast CT to monitor for hemorrhagic transformation. |
| What level should blood pressure be maintained if the patient has received IV alteplase? What level should be maintained if the patient has not received IV alteplase? | If no IV alteplase: < 220/110 mmHg. |
| | If already given IV alteplase: < 180/105 mmHg. |
| In what circumstances should a patient receive long-term anticoagulation after ischemic stroke? | Atrial fibrillation, hypercoagulable disorders, mechanical prosthetic heart valves, and acute myocardial infarction. |
| What is the "double-flush technique" and why is it useful? | This refers to using one syringe to aspirate the catheter and remove any air bubbles present in the line. This syringe is discarded and a second syringe devoid of air bubbles is then used to push forward flow. In this technique, interventional radiologists can be sure to avoid sending air bubbles into arterial circulation and causing further embolic ischemic damage to the brain. |

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| List the three most common sites of intracranial berry (saccular) aneurysms. | Most common sites include: anterior communicating artery (35%), internal carotid artery including branches (30%), and middle cerebral artery (22%). Note that 85% of saccular intracerebral aneurysms occur at the Circle of Willis. |
| Vasospasm occurs in the 3–12 day window following SAH and can be diagnosed with transcranial Doppler. What are its typical signs and symptoms? | Confusion, restlessness, decreased sleep, aphasia, hemiparesis |

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# Chapter 44
# Percutaneous Vertebral Augmentation

**Ryan Bitar, Barrett O'Donnell, and Charles Hyman**

## Evaluating Patient

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| Describe the prevalence of vertebral compression fracture in the United States. | Approximately 1.5 million cases of VCF occur annually in the general US population. VCF most commonly occurs in the elderly population (40% prevalence by age 80), particularly women; 25% of all postmenopausal women in the United States will experience a VCF in their lifetime. |

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| What are the most common risk factors for vertebral compression fracture (VCF)? | Osteoporosis is by far the most common etiology for VCF; however, other significant causes include trauma, infection, and neoplasm. Osteoporosis is most commonly seen in post-menopausal women due to hormonal changes leading to decreased bone mineral density and bone fragility prone to fracture. |
| Most common presentation of VCF? | While many fractures may develop insidiously and may be detected incidentally in asymptomatic patients with risk factors, symptomatic patients may present with sudden-onset severe focal back pain that may radiate anteriorly and may be confused with cardiac or pulmonary disease. The pain is usually exacerbated by standing, sitting up, or ambulating and improved by lying down. The patient may demonstrate kyphosis, midline spinal tenderness, and impaired respiratory function. |
| Where do most VCF occur? | While compression fractures may occur anywhere from the occiput to the sacrum, they most commonly occur at the lumbodorsal junction. Most usually, T8-T12, L1, and L4. |
| How is the evaluation and diagnosis of vertebral compression fracture conducted? | Physical exam should include neurological assessment to rule out nerve/spinal compression. Initial diagnostic imaging should include plain radiograph, with the classic finding of an anterior wedge fracture. Criteria for VF includes a decrease in vertebral body height by 15–20% from baseline height. |

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| What additional imaging workup is useful when planning vertebral augmentation therapy? | While initial imaging should always consist of plain radiograph of the spine and is often the only imaging necessary for a majority of compression fractures. If necessary, CT demonstrates improved anatomy for the assessment of loss of height and spinal canal compromise. MRI will provide the best information regarding the fracture age, as it may show bony edema for acute fracture. Additionally, MRI short TI inversion recovery (STIR) sequence may be useful for surgical evaluation of fracture stability. A post-contrast MRI study will detect a pathologic fracture secondary to oncologic process. |

## High Yield History

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| What is the pathophysiology behind the occurrence of a vertebral compression fracture? | VCF occurs when the weight of the upper body exceeds the capacity of a vertebral body to support that weight, usually precipitated in the event of trauma. Conditions such as osteoporosis which lower the bone mineral density thus lower the severity of the trauma necessary for fracture such as tripping, lifting a heavy object, or even sneezing. A healthy spine may still be at risk for VCF in the setting of severe trauma such as a motor vehicle collision or hard fall. |
| What would serve as the surgical alternative prior to the use of percutaneous vertebral augmentation for the treatment of compression fractures? | Prior to the implementation of PVA, the surgical rectification of compression fractures involved decompression and fusion of the vertebrae. This method would often fail in the elderly usually due to underlying osteopenia or osteoporosis. |

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| How may one detect VCF in a cancer patient with back pain? | A proper evaluation of the patient is crucial to assess the attributability of the back pain to tumor burden. Focal pain should be present at the lesion site, should worsen with weightbearing, and be relieved with the recumbent position. Pain should lack neurological symptoms and typically be severe enough to affect daily activity beyond the scope of medical management. |

## Indications/Contraindications

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| What are common indications for percutaneous vertebroplasty? | According to the Society of Interventional Radiology, common indications include: osteoporotic vertebral compression fracture older than 2 weeks and refractory to medical therapy, painful vertebra with extensive osteolysis, or invasion secondary to malignant tumor. |
| What are indications for an extrapedicular approach versus the preferred transpedicular approach? | The extrapedicular (posterolateral) approach may be selected when the patient presents with factors that make the transpedicular approach difficult such as having a small pedicle, pedicular lysis, or pedicle screws. |
| What are the contraindications to PVA? | The absolute contraindications include hemorrhagic diathesis, asymptomatic fracture, cement allergy, and infection. Lesions with epidural extension are relatively contraindicated for treatment with vertebroplasty or kyphoplasty, as they carry a higher risk of posterior cement extravasation. |

## Relevant Anatomy

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| Describe the general components of the spine. | The human spine consists of 24 vertebrae (7 cervical, 12 thoracic, 5 lumbar) along with the sacrum and the coccyx. There is a normal lordosis to the cervical and lumbar regions and a mild kyphosis to the thoracic and sacral regions. The vertebral arteries run through the transverse foramina of the cervical spine. Thoracic vertebrae have a rib attached to each lateral side. The sacrum consists of 5 fused segments and the coccyx consists of 4 segments with a variable fusion pattern. |
| Describe the general structure of a vertebra. | Each vertebra is separated via intervening discs. Each vertebra consists of a body anterior to the spinal canal, a pedicle which attached the body to the transverse process on each lateral side of the spinal canal, and 2 lamina which connects each transverse process to the posterior spinous process. |
| Describe the anatomy of the lumbar as compared to the thoracic vertebrae. | Distinguishing features of the lumbar vertebrae include larger vertebral body, a shorter and thicker spinous process which projects more perpendicular from the body. Facets have a curved articular surface. The thoracic spine vertebrae are most distinguished by the presence of costal facets. Their spinous processes angulate downward. The thoracic vertebrae have smaller pedicles and are more prone to severe kyphotic fractures than lumbar vertebrae, presenting a challenge to execute the transpedicular approach. |
| Describe the anatomy of the intervertebral discs. | The intervertebral discs consist of three components: a thick outer ring of fibrous cartilage (the annulus fibrosis), the gelatinous core (the nucleus pulposus), and the vertebral endplates, which contact the vertebrae. They are avascular and receive their nutrients via diffusion. |

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| Describe the blood flow of the vertebral bodies and spinal cord. | The vertebral bodies, epidural space, and nerve roots are supplied directly from arterial branches which leave the aorta. In regard to the spinal cord, anterior segmental medullary vessels from the aorta supply the anterior spinal artery, which perfuses the anterior 2/3 of the spinal cord. Two posterolateral spinal arteries supply the posterior third of the spinal cord. |
| What anatomical structures may be at risk in the case of posterolateral approach? | Particularly in the case of thoracic spine, the posterolateral approach introduces the concern of injuring the pleura and lungs through the needle track, potentially introducing a risk of hemothorax. In the case of the lumbar spine, there lies a risk in psoas hematoma or even retroperitoneal organ injury. |

## Relevant Materials

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| What are the basic tools used for this procedure? | Typically, the procedure occurs in a fluoroscopy suite with conscious sedation. Multiple views are utilized to ensure precise anatomical location. Local anesthetic with 1% lidocaine is usually [employed]. Beveled, 11 or 13 G styleted bone needles are used for penetrating the target site at the anterior third of the vertebral body. A small mallet is used to push the needle forward into position. In the case of kyphoplasty, a hand drill and balloon with an inflation device are employed. Various compounds are available for augmentation, including poly (methyl methacrylate) (PMMA)-based acrylic cements and biodegradable calcium phosphate cement (CPC). |

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| How does vertebral augmentation cement differ from cement used in other surgical procedures, such as arthroplasty? | In addition to having sustainable mechanical strength, vertebral augmentation cement should be adequately viscous for injection, have an appropriate setting time, and provide adequate contrast during fluoroscopic imaging. |
| Is general anesthesia necessary for this procedure? | Not routinely. Conscious sedation and local anesthetic may be suitable options for this intervention. A combination of midazolam and fentanyl are suitable options for intraprocedural pain and anxiety management. |

## General Step by Step

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| What preprocedural steps should be taken? | The patient should be NPO after midnight for a morning procedure or at least 6 hours prior to an afternoon procedure. Small sips of water and medication are acceptable. Anticoagulation should be discontinued prior to the procedure. Relevant laboratory studies include complete blood count and coagulation studies. |
| Why is the transpedicular approach preferred over the posterolateral approach, and why must the medial aspect of the pedicle be avoided? | Most frequently, the transpedicular route is preferred; this approach lessens the risk of injury to the pleura or lung, which are complications potentially attributable to the posterolateral approach. It is critical to avoid the medial aspect of the pedicle as to avoid intrathecal transgression, which may damage intrathecal contents or allow for extravasation of cement into the intrathecal space. |

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| What is the preferred positioning of the patient and location of initial incision of the trocar needle for the transpedicular approach? | The patient usually resides in the prone position. The initial incision is made is made ~1–1.5 cm lateral to the pedicle lateral margin. |
| Describe the technique for trocar needle positioning prior to advancement via the transpedicular approach. | Most commonly, the pedicle of interest is localized and an ipsilateral oblique projection is utilized to look down the "barrel" of the pedicle. The needle, pedicle, and targeted position in the anterior one-third of the vertebral body are lined up like a "bulls-eye." |
| What are some guidelines regarding the injection of cement into the vertebral body? | Cement should be injected slowly and under lateral fluoroscopic view. It is important to take care not to overfill in order to reduce the risk of cement extravasation. Though operator dependent, injection should be halted once cement distribution begins to reach the posterior third of the vertebra body. |
| Describe the post-operative management for the patient. | Patients should be subjected to 2 hours of bed rest post-operatively. The patient may walk once their symptoms are tolerable and may be discharged the same day of the procedure. |

## Complications

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| Most feared complications of PVA? | Extravasation of cement is considered a minor complication of vertebroplasty, though it can be more serious when approaching the posterior one-third as their is potential to damage the spinal cord or even exiting nerve roots. Venous intravasation into the vertebral venous plexus of veins may lead to pulmonary embolism. |

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| What are the other general complications of percutaneous vertebroplasty? | Vertebroplasty appears to demonstrate an overall complication rate of about 1–10%. Most complications include infection, pain exacerbation, bleeding, a transient radiculopathy, and fracture. |
| What risk factors increase the risk of cement leakage? | One meta-analysis suggested that intravertebral cleft, cortical disruption, low cement viscosity, and high volume of injected cement may be high risk factors for cement leakage post-vertebroplasty. |
| A patient develops isolated radicular pattern pain. What is the next step in management? | Uncommonly, cement may leak adjacent to a nerve root, which may produce radicular pain. Analgesics combined with local steroids or anesthetics may provide adequate management of this pain, so long as there is no associated focal neurological deficit associated with the pain. |
| If a patient develops a focal neurological deficit post-operatively, how should this patient be managed? | The patient should undergo immediate neurosurgical consult, as it is likely a significant cement leak has occurred. A CT scan would highly be beneficial in order to assess the size and location of the suspected cement leak. |
| What are overall techniques to limit the risk of substantial cement leaks? | Substantial cement leaks may be avoided with the use of high-resolution fluoroscopy, and while not necessary, biplane fluoroscopy greatly facilitates the visualization of cement formation during the procedure. Patients with additional factors that limit good visualization, such as obesity or severe osteoporosis, may benefit from the use of combined fluoroscopy and CT imaging. Good cement opacification is crucial for early recognition of a leak, which requires the inclusion of barium sulfate as an opacification agent in the cement preparation. |

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## Landmark Research

Van Meirhaeghe J, Bastian L, Boonen S, et al. A randomized trial of balloon kyphoplasty and nonsurgical management for treating acute vertebral compression fractures: vertebral body kyphosis correction and surgical parameters. *Spine (Phila Pa 1976)*. 2013;38(12):971–983. doi:https://doi.org/10.1097/BRS.0b013e31828e8e22

- The FREE trial was a randomized clinical trial comparing nonsurgical management vs balloon kyphoplasty for the treatment of acute vertebral compression fractures.
- The study concluded that over the course of two years, pain, function, kyphotic angulation, and overall quality of life were improved in comparison to nonsurgical management.

Klazen CA, Verhaar HJ, Lampmann LE, et al. VERTOS II: percutaneous vertebroplasty versus conservative therapy in patients with painful osteoporotic vertebral compression fractures; rationale, objectives and design of a multicenter randomized controlled trial. *Trials*. 2007;8:33. Published 2007 Oct 31. doi:https://doi.org/10.1186/1745-6215-8-33

- VERTOS II study, open-label RCT comparing vertebroplasty and conservative therapy, concludes that the technique is effective and safe, with immediate pain relief sustained for at least one year greater than achieved by conservative management. No difference in adjacent VCF.

Clark W, Bird P, Gonski P, et al. Safety and efficacy of vertebroplasty for acute painful osteoporotic fractures (VAPOUR): a multicentre, randomised, double-blind, placebo-controlled trial [published correction appears in Lancet. 2017 Feb 11;389(10069):602]. *Lancet*. 2016;388(10052):1408–1416. doi:https://doi.org/10.1016/S0140-6736(16)31341-1.

Buchpinder, et al. A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures. New England

Journal of Medicine. 2009 August; 361: 557–568. DOI: https://doi.org/10.1056/NEJMoa0900429

- Data regarding percutaneous vertebroplasty versus sham procedure.
- It is unclear in literature which is superior. A 2009 NEJM randomized clinical trial for vertebroplasty for osteoporotic VCF showed no difference between vertebroplasty and sham procedure.
- VAPOUR trial was more selective in patient recruiting, better designed and masked trial demonstrating a benefit from percutaneous vertebral augmentation.

Wang B, Zhao CP, Song LX, Zhu L. Balloon kyphoplasty versus percutaneous vertebroplasty for osteoporotic vertebral compression fracture: a meta-analysis and systematic review. *J Orthop Surg Res*. 2018;13(1):264. Published 2018 Oct 22. doi:https://doi.org/10.1186/s13018-018-0952-5

- A meta-analysis performed by Wang et al. in 2018 demonstrated no significant difference in clinical outcomes and yield equally effective treatment modalities in the setting of osteoporotic vertebral compression fracture, even though kyphoplasty demonstrates the advantage of decreasing the kyphotic wedge angle, thus increasing the vertebral body height.

## Common Questions

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| How rapid is symptom improval following percutaneous vertebral augmentation? | PVA treatment in the case of osteoporotic vertebral fractures is associated with immediate and significant long-term improvement in back pain, as well as quality of life due to improved functionality. |

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| What are the origins of the first vertebroplasty performed? | The first percutaneous vertebroplasty was performed in 1984 by two French interventional neuroradiologists (Gakibert and Deramond) where they injected PMMA into the C2 vertebra to treat a painful vertebral hemangioma; the patient's pain was alleviated. Later, PMMA was employed to treat osteoporotic vertebral fractures. |
| What is the main difference of kyphoplasty as compared to vertebroplasty? | In kyphoplasty, a balloon is used to create a cavity in the fractured vertebra, providing a low-pressure lumen for the filling of cement, thereby lowering the injection pressure and lowering the risk of cement leakage. |
| What are some medical therapies for VCF? | First-line medical therapy for vertebral compression fracture usually consists of conservative pain management. Most commonly, NSAIDs are the first analgesic of choice given their safety and low cost; opioids for long-term pain control remains largely controversial. Patients with underlying osteoporosis and nontraumatic compression fracture should receive bone-supporting medication such as bisphosphonates, hormone replacement therapy, and supplemental vitamin D and calcium. Orthotic bracing and physical therapy provide added benefit for fracture recovery, as well. Unfortunately, none of these added therapies can restore the loss of height or reduce kyphotic deformity. |
| What are the main two types of percutaneous vertebral augmentation (PVA) and how do they differ? | both vertebroplasty and kyphoplasty are performed under fluoroscopic guidance. Vertebroplasty involves the percutaneous injection of bone cement into cancellous bone of a vertebral body in order to alleviate pain and counter bone height loss. Kyphoplasty includes the inflation of a balloon to generate a cavity for the cement to be injected. |

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| How is bone mineral density assessed and what is the distinction between osteoporosis and osteopenia? | Once a patient has received an initial diagnosis of compression fracture, bone density should be assessed using a DEXA scan. A DEXA scan will provide a T score which directly compares the bone mineral density of the patient to the mean bone mineral density of the young adult population. A T score between −2.5 and −1.0 defines osteopenia. A T score < −2.5 provides a diagnosis of osteoporosis. |
| How long before a VCF is healed and how can patients decrease the risk of future VCF? | Full recovery (or significant improvement) can be expected six to twelve weeks once the fracture has healed. Activities such as well-balanced diet, regular exercise, smoking cessation, and osteoporosis medication can prove helpful in the prevention of future fractures. |
| Could a unilateral percutaneous vertebral augmentation prove to be as efficacious as the traditional bilateral approach? | Early in the development in the procedure, percutaneous vertebral augmentation was bilateral; however, a unilateral approach is becoming adopted. While a unilateral approach would reduce surgical time and reduce overall complication rate, concerns still linger in regard to the efficacy of a unilateral approach; however, studies demonstrate that there is no difference in clinical or radiological outcomes between unilateral or bilateral approaches. |

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# Chapter 45
# Management of Benign and Malignant Back Pain by Interventional Radiology

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## Evaluating the Patient

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| What are the key medical questions to address in a patient presenting with musculoskeletal pain? | 1. How does the patient characterize the pain?<br>Location, duration, severity, exacerbating and relieving factors, prior radiation, associated neurological deficits (weakness, numbness, paresthesia, bladder and bowel deficits), and effect on activities of daily living.<br>2. Can the described pain be correlated to an abnormality on recent imaging? What is the origin of that imaging abnormality?<br>Trauma, degenerative disease (disc, cartilaginous, osseous), infection, or tumor.<br>3. Does a biopsy need to be performed to provide a definitive diagnosis before treatment?<br>4. What noninvasive treatment can the patient undergo to alleviate this pain?<br>Oral pain regimen such as nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, opioids, and herbal/traditional medication<br>Non-oral pain treatments such as topical creams and patches (lidocaine patches), thermal therapy (ice or heat packs), and transcutaneous electrical nerve stimulation (TENS)<br>5. Have there been prior non-medicinal treatments for this pain?<br>Physical therapy, steroid injections, locoregional ablation or radiation therapy, and surgery.<br>6. What was the response to these treatments, or why were these not pursued? |

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| In patients who present with pain presumed to be from degenerative disc or osseous disease, what factors may indicate a cancerous or infectious etiology that will require further work-up with additional imaging and/or biopsy? | Atypical symptoms for degenerative disease include fever, chills, night sweats, fatigue, decreased appetite, unintentional weight loss, nonmechanical resting pain, nocturnal pain.<br>Cancer risk factors include age >50 years, frequent tobacco or alcohol use, and personal or family history of malignancy.<br>Infection risk factors include immunosuppression (HIV, prolonged corticosteroid use, recent chemotherapy, bone marrow transplant), intravenous drug use, recent or current bacterial infection (especially skin or urinary tract infection), failure of response to initial treatment/therapy. |
| What are common reasons for a vertebral compression fracture? | Trauma<br>Osteoporosis<br>Tumor<br>Infection |
| What is the treatment for a vertebral body compression fracture? | Conservative (rest and bracing)<br>Vertebral augmentation, which includes the treatment options of vertebroplasty and kyphoplasty (Fig. 45.1) |
| What is the difference between vertebroplasty and kyphoplasty? | *Vertebroplasty* is the stabilization of a vertebral compression fracture deformity with the percutaneous injection of a bone filler, commonly polymethyl methacrylate (PMMA) or a calcium phosphate compound. These bone fillers, colloquially known as bone cement, harden to provide resistance to axial compression forces, thus stabilizing the bone.<br>*Kyphoplasty* is similar in concept to vertebroplasty but undertakes an additional step to restore the vertebral body height before the injection of the bone filler. |

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| What are common degenerative etiologies for spine pain? | Facet hypertrophy, which can cause arthritic pain and also cause irritation and inflammation of the adjacent median branch nerve<br>Discogenic pain<br>Lateral or para-medial disc protrusion into the spinal canal, causing foraminal nerve root impingement<br>Central disc bulge into the spinal canal, causing spinal canal stenosis or nerve root compression<br>Sacroiliac degenerative changes leading to joint inflammation |
| What is a common minimally invasive method to treat discogenic pain? | Epidural steroid injection. |
| What clinical features suggest degenerative low back pain originates from a facet joint? | Chronic low back stiffness with unilateral low back pain that is most pronounced in the morning and improves as the day progresses. In addition, there is typically absence of radiculopathy, pain aggravation by rotation/lateral bending/hyperextension, and pain relief by flexion. |
| What are percutaneous treatment options for facet joint arthropathy? | Median nerve branch block<br>Median nerve branch ablation (rhizotomy)<br>Facet joint steroid injection |

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| What is the best objective method to determine whether degenerative low back pain originates in the sacroiliac joint? | Pain palliation with steroid injection directly into the sacroiliac (SI) joint. |
| What more invasive percutaneous treatment may be pursued if a patient with sacroiliac joint disease does not have prolonged relief with SI joint steroid injection? | Sacroiliac joint fusion with implant. |
| What are percutaneous IR treatment options to palliate a sacral fracture? | Cementoplasty is the application of vertebral augmentation techniques outside of the vertebral body. When applied to the sacrum, cementoplasty can be referred to as sacroplasty. The sacrum is accessed with bone needles, and a bone cement is injected to stabilize the fracture and reinforce the bone. Percutaneous screw fixation, also known as fixation by internally cemented screw (FICS). This technique applies advanced imaging to place a cannulated screw across the fracture before filling in the fracture with PMMA (Figs. 45.2, 45.3). |
| What are common minimally invasive image-guided procedures to ameliorate neuropathic pain? | Epidural steroid injcetion<br>Sacro-iliac joint steroid injection<br>Spinal nerve root block<br>Facet steroid injection<br>Rhizotomy of the median branch nerves (Fig. 45.4). |

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| What are common minimally invasive image-guided procedures to ameliorate neuropathic pain? | Epidural steroid injcetion<br>Sacro-iliac joint steroid injection<br>Spinal nerve root block<br>Facet steroid injection<br>Rhizotomy of the median branch nerves (Figs. 45.2, 45.3, and 45.4). |

## High Yield History

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| What are two scales commonly used to assess musculoskeletal back and pelvic pain? | *Visual analog scale:* A patient self-reported 10-point scale, with 0 on the left (no pain) and 10 on the right (extreme pain) as anchor points. To perform the visual analog scale appropriately, the patient should select the number based upon the face associated with that number. In common practice, the visual component might not be involved. Patients can be asked for maximum, minimum, and average pain levels in different activities (resting, sitting, standing, and walking). This scale is commonly used to assist in oral pain medical distribution.<br>*Oswestry Disability Index:* In-depth patient self-reported questionnaire designed to characterize back pain based upon functional impact, including pain intensity, personal hygiene, activity, and impact on social functions. Each section is scored on a 6-point scale (0–5), with a higher score indicating a higher level of disability. The numeric summation of all 10 sections is calculated as [(total scored)/(total possible score) × 100] and can be used to trend response to treatments over time. |

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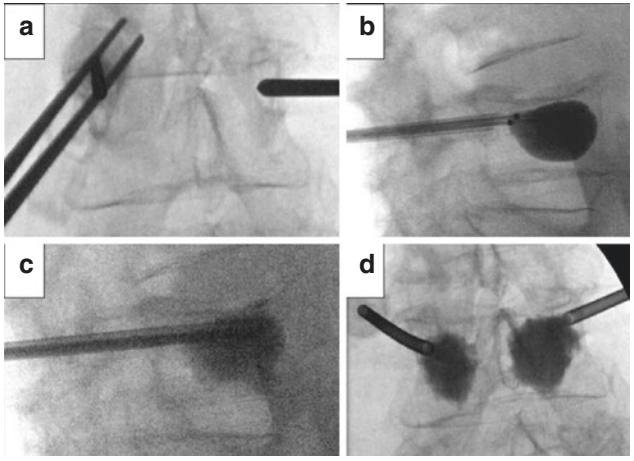


Figure 45.1 Kyphoplasty of a painful L4 vertebral compression fracture deformity using a bipedicular needle placement (**a**), balloon inflation (**b**), and PMMA injection under fluoroscopy ((**c**) sagittal view, (**d**) AP view)

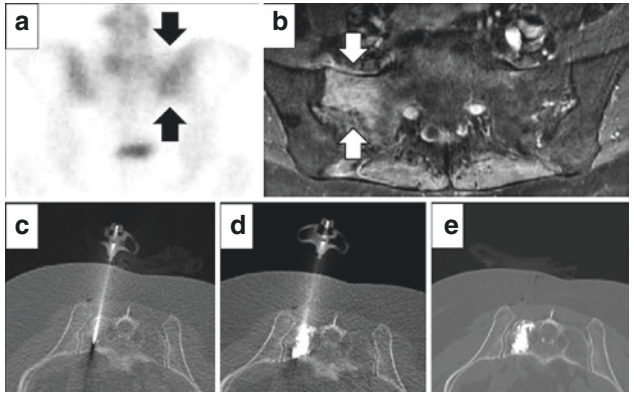


Figure 45.2 Insufficiency fracture of the right sacral ala causing significant weight-bearing pain ((**a**) bone scan with increased activity in the right sacrum, arrow, (**b**) MRI with contrast with increased intensity, arrow). Intra-procedural CT axial images during cementoplasty, with needle placement in a posterior short-axis approach (**c**), followed by PMMA injection (**d**), and final procedure image with needle removed (**e**)

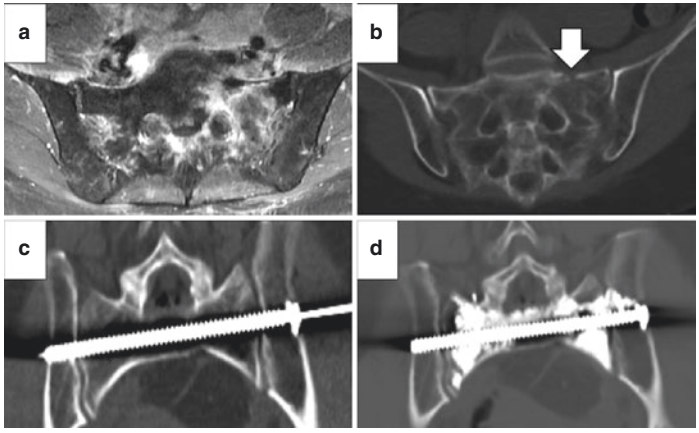


FIGURE 45.3 Painful, non-healing left sacral fracture from radiation-induced osteoporosis as a complication of colon cancer treatment ((**a**) MRI axial post-contrast with left sacral hyperintensity, (**b**) oblique axial CT image with cortical disruption, arrow), treated with fixation by internally cemented screw ((**c**) CT procedural oblique coronal image demonstrated cannulated screw advanced over a Kirschner wire, (**d**) CT procedural oblique coronal image after PMMA injection around the screw)

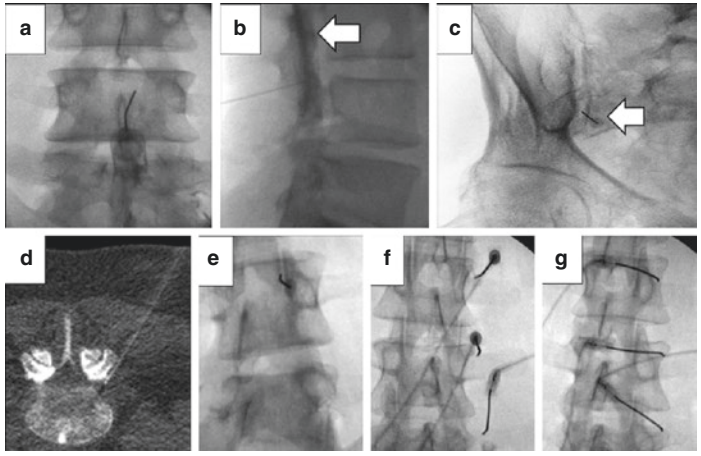


FIGURE 45.4 Epidural steroid injection ((**a**) anterior-posterior projection, (**b**) sagittal projection with arrow identifying contrast layering in the epidural space). Right sacro-iliac joint steroid injection ((**c**), arrow). Spinal nerve root block at the left L4 neuroforamen under CT guidance (**d**). Steroid injection into the right L4/5 facet ((**e**), obliqued anterior-posterior view). Rhizotomy for the right L2-L4 median branch nerves ((**f**) anterior-posterior projection, (**g**) obliqued projection)

## Indications/Contraindications

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| What are the two broad indications for epidural steroid injections (ESI)? | Diagnostic intervention to confirm the source of back pain<br>Therapeutic intervention to provide temporary pain relief in the setting of radiculopathy in patients with discogenic or other spinal canal pathology, unspecified nerve pain, and recurrent radiculopathy post-laminectomy |
| What are the two broad indications for selective nerve root blocks (SNRB)? | Diagnostic intervention to confirm the source of back pain<br>Therapeutic intervention to provide temporary pain relief in the setting of radiculopathy in patients with disc herniations and recurrent radiculopathy post-discectomy |
| What are the contraindications to steroid injections? | Absolute:<br>Coagulopathy<br>Active infection<br>Pregnancy<br>Maximum recommended corticosteroid dose reached<br>Relative:<br>Allergy to anesthetic or corticosteroid |
| What are the limitations for radiofrequency ablation (rhizotomy) in the treatment of median branch nerve inflammation caused by facet hypertrophy? | Anatomic variability. |

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| What are the indications for vertebral augmentation? | Mechanical, weight-bearing pain in the spine that affects daily quality of life and has not improved with conservative measures<br>Imaging that confirms a vertebral body compression fracture that correlates with the location of the mechanical pain |
| What are absolute and relative contraindications for vertebral augmentation? | Absolute:<br>Unstable vertebral column fractures better treated with surgical fixation<br>Active infection<br>Coagulopathy<br>Relative:<br>Fracture protrusion into the spinal canal<br>Tumor erosion through the posterior wall of the vertebral body that increases risk for bone filler injection to enter the spinal canal<br>Vertebral planum that precludes bone filler injection |

## Relevant Anatomy

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| Review the below depiction of important spinal anatomy to refer to throughout this chapter (Figs. 45.5 and 45.6). | |
| In the approach to spinal nerve root injection for the L1-L4 levels, what location has been termed the fluoroscopic "safe triangle" for needle passage? | The margins include the pedicle superiorly, the lateral border of the vertebral body laterally and the outer margin of the spinal nerve medially. Needle tip placement into this location minimizes the risk of damage to the nerve root as it exits the neuroforamen (Fig. 45.7). |

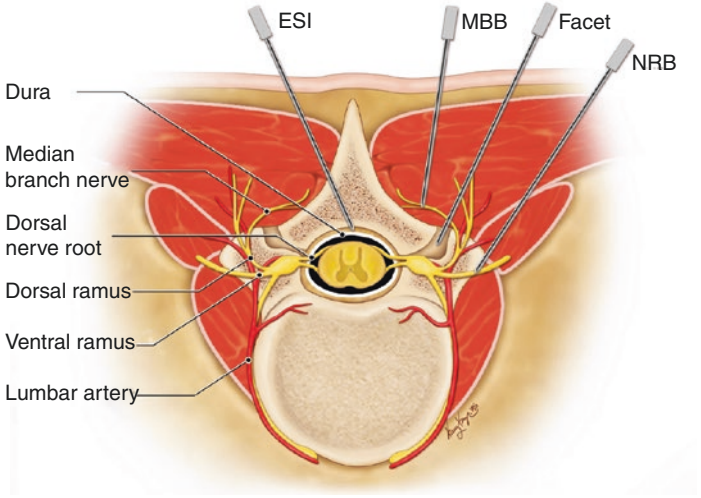


FIGURE 45.5 Spinal anatomy detailed above, with the following abbreviations detailed below. Dura dura mater, ESI epidural steroid injection, MBB medial branch block, Facet facet joint, NRB nerve root block

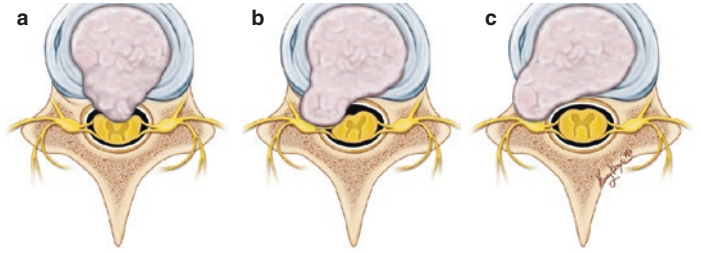


FIGURE 45.6 (**a**) *central vertebral disc herniation*, which is a posterior-facing bulge with the potential to interfere with the spinal cord. (**b**) *paramedial vertebral disc herniation,* also known as posterolateral herniated disc, which results from a disc bulge off-center (left or right) and asymmetric into the lateral recess on the side of the spinal cord. (**c**) *extreme lateral vertebral disc herniation*, which is a disc bulge outside of the spinal canal causing nerve root compression at the level above the prolapsed disc

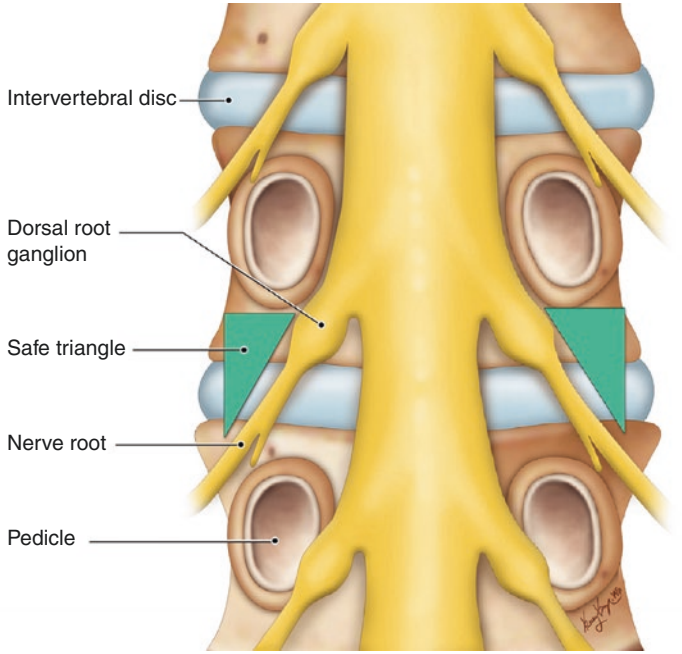


FIGURE 45.7 The safe triangle (green triangle) is the best approach when administering a spinal nerve root injection at L1-L4 levels and includes the following margins: the pedicle as the superior border, the lateral edge of the vertebral body as the lateral border, and the outer margin of the spinal nerve as the medial diagonal border

## Relevant Materials

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| What is typically used for spinal nerve root blocks and epidural spinal injections? | Diagnostic injection: 1–2 mL of 2% lidocaine or 0.25%–0.5% bupivacaine<br>Therapeutic injection: 1–2 mL of 2% lidocaine or 0.25%–0.5% bupivacaine + 1 mL of corticosteroid<br>Example of a common steroid solution: 40 mg triamcinolone and 2 mL 0.5% bupivacaine (total volume of 3 mL)<br>Injection volume of anesthetic and/or corticosteroid typically should not exceed 3 mL |
| What is typically used for facet injections? | Diagnostic injection: 0.5–1.5 mL of 2% lidocaine or 0.5% bupivacaine<br>Therapeutic injection: 0.5–1.5 mL of 2% lidocaine or 0.5% bupivacaine + 0.5–1 mL of corticosteroid<br>Injection volume of anesthetic and/or corticosteroid should typically not exceed 2 mL |
| When and why might particle-free steroid be used for a steroid injection? | Particle-free steroid, such as dexamethasone, may be more appealing to inject at the neuroforamen to minimize the risk of embolization of a radicular arterial branch that may contribute to the anterior spinal artery. If a particulate steroid is injected into a branch of the anterior spinal artery, this may result in spinal cord injury and paralysis. Particle-free steroids are also recommended for cervical (neck) epidural injections given the smaller epidural space at this level. |

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| What are the common types of bone fillers that can be percutaneously injected for vertebral body compression fractures and sacral fractures? | Polymethyl methacrylate (PMMA) is a nonresorbable bone filler with high compression resistance.<br>Calcium phosphate cements, derived from hydroxyapatite, are resorbable bone filler alternatives that are not as hard as PMMA and have less compression resistance. This may be more appropriate for osteoporotic fractures to minimize the risk of secondary fractures of adjacent vertebral body levels. |

## General Step by Step

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| What are common treatment options for lumbar radiculopathy? | *Conservative measures:* Physical therapy, structured exercise programs, spinal manipulation, traction (manual or mechanical)<br>*Pharmacologic interventions:* NSAIDS, tumor necrosis factor alpha inhibitors, glucocorticoids, 5-hydroxytryptamine receptor inhibitors, gabapentin, agmatine sulfate, amitriptyline<br>*Image-guided needle-directed therapy:* spinal nerve root block and epidural steroid injection<br>*Surgery:* anterior lumbar/extreme lateral/transforaminal lumbar/posterior lumbar interbody fusion, lumbar laminectomy, lumbar microdiscectomy, laminotomy, lumbar spinal fusion, cage implantation, pedicle screw, deformity correction |
| During SNRB, what two factors will jointly confirm appropriate needle tip position before injection? | Radicular pain elicited by the needle tip.<br>Contrast injection opacifies the neuroforamina. |

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| During ESI, what confirms appropriate needle tip position within the epidural space? | Entrance into the epidural space will be accompanied by a sudden loss of resistance to pressure applied through a saline or air-filled syringe connected to the needle hub. |
| What are the (2) types of facet procedures? | *Intra-articular injection:* The source of facet pain may be directly related to arthritic inflammation within the joint. An intra-articular injection of anesthetic and/or corticosteroid into the joint space can relieve this primary pain source.<br>(a) Diagnostic: Injection of local anesthetic agent directly into the facet joint can identify if pain is localized to the joint itself.<br>(b) Therapeutic: Injection of both local anesthetic for short-term pain relief and corticosteroid for more prolonged pain relief.<br>*Medial branch nerve block (MBB):* The medial branch nerve provides sensory innervation to the facet joint. An MBB inhibits the transmission of pain signals from facet joints and relieves indirect nerve inflammation caused by mechanical friction of the hypertrophied facet joint with the median branch nerve.<br>(a) Diagnostic: Injection of local anesthetic agent adjacent into the soft tissue immediately lateral to the facet can identify if pain is caused by either the facet or a local irritation of the associated median branch nerve.<br>(b) Therapeutic: Injection of both local anesthetic for short-term pain relief and corticosteroid for more prolonged pain relief. |

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| What methods confirm needle placement within the facet during facet injection? | Pressure resistance during needle advancement decreases with entry into the joint.<br>Patients typical describe decreased procedural pain stimulus upon needle entry into the joint.<br>Contrast injection through the needle will layer within the facet joint. |

## Complications

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| What are possible side effects from steroid injections? | Abnormalities in blood glucose levels, particularly in diabetic patients<br>Sleeplessness/insomnia<br>Mood disturbances<br>Transient immunocompromised state with or without abnormal white blood cell count |
| What are possible complications for spine injections? | Infection<br>Bleeding<br>Spinal fluid leakage causing decreased intracranial pressures and/or spinal fluid hydrocele |
| List some specific complications for spinal nerve root blocks and epidural spinal injections? | *Nerve root blocks:* needle trauma resulting in continued or worsened radicular pain, weakness/paresthesia, and rarely vascular occlusion/thrombosis that can cause spinal cord infarction if the radiculomedullary artery is injected with steroid containing particles<br>*Epidural spinal injections:* needle trauma causing dural puncture, epidural hematoma, and spinal fluid leak that may result in headaches or spinal fluid hydrocele that might require surgery or blood patch |

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| What are possible complications of palliative radiofrequency ablation (rhizotomy) treatments? | Damage to surrounding structures (muscle, nerve, bone)<br>Hemorrhage<br>Infection<br>Skin burn |
| What are possible complications of vertebral augmentation or sacroplasty?27 | Cement leakage that compresses a spinal cord or nerve root<br>Cement leakage into the periosteal venous plexus with cement embolus to the lungs |
| What are possible complications of percutaneous sacral fixation or fusion? | Bleeding due to damage of a gluteal or internal iliac branch artery<br>Infection<br>Nerve damage due to procedural trauma (screw misplacement or cement leakage) |

## Landmark Research

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| What are landmark research trials in support of and against vertebral augmentation? Please see the dedicated chapter on vertebral augmentation for additional references. | Kallmes DF, Comstock BA, Heagerty PJ, et al. A randomized trial of vertebroplasty for osteoporotic spinal fractures. [published correction appears in N Engl J Med. 2012 Mar 8;366(10):970]. *N Engl J Med*. 2009;361(6):569–579. doi:https://doi.org/10.1056/NEJMoa0900563.<br>VERTOS IV Trial: Firanescu CE, de Vries J, Lodder P, et al. Vertebroplasty versus sham procedure for painful acute osteoporotic vertebral compression fractures (VERTOS IV): randomised sham controlled clinical trial [published correction appears in BMJ. 2018 Jul 4;362:k2937. Smeet AJ [corrected to Smeets AJ]]. *BMJ*. 2018;361:k1551. Published 2018 May 9. doi:https://doi.org/10.1136/bmj.k1551<br>VAPOUR Trial: Clark W, Bird P, Gonski P, et al. Safety and efficacy of vertebroplasty for acute painful osteoporotic fractures (VAPOUR): a multicenter, randomized, double-blind, placebo-controlled trial. The Lancet. 2016; 388(10052):1408-1416.<br>EVOLVE Trial: Beall DP, Chambers MR, Thomas S, et al. Prospective and Multicenter Evaluation of Outcomes for Quality of Life and Activities of Daily Living for Balloon Kyphoplasty in the Treatment of Vertebral Compression Fractures: The EVOLVE Trial. *Neurosurgery*. 2019;84(1):169–178. doi:https://doi.org/10.1093/neuros/nyy017 |

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| What were the key findings by Sasso et al. regarding the application of selective nerve root blocks as a pre-operative intervention to confirm pain source and decrease reoperation rates for surgical decompression? | Selective nerve root injections as a diagnostic test to identify the source of pain and predicting surgical outcomes had a positive predictive value of 91.2% and a negative predictive value of 40.0%.<br>Although the surgical decision to treat is heavily guided by local MRI abnormalities, the negative predictive value of selective nerve root injections was significantly better than MRI findings ($z = 2.46$, $P = 0.01$) to identify the source of pain.<br>Of the 91 patients in this study, seven patients had an initial negative selective nerve root injection, followed by a positive selective nerve root injection at an adjacent level.<br>All seven of these patients went on to have positive surgical outcomes. |
| Manchikanti et al. published a randomized, double-blind, active-control trial on the effectiveness of lumbar interlaminar epidural injections in disc herniation comparing treatments with and without steroids. Did this study show any superiority in the group that obtained anesthetic + steroid vs. those who solely received local anesthetic? | Both groups showed an overall significant improvement in numeric pain score and Oswestry Disability Index over the two-year study period.<br>Despite the lack of a significant difference between the groups, there was a general superior pain relief at 6 months in the steroid group, and similarly improved functional status at both 6 and 12 months.<br>The steroid group only had one treatment failure, compared to ten in the local anesthetic group, suggesting that the inclusion of steroid may increase rates of treatment success. |

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| In their application for pain palliation of bone metastases, what (2) ablation modalities are the most commonly used with robust literature to support their use? 1 | Radiofrequency ablation<br>Cryoablation |
| In regard to treatment of metastatic bone tumors with cryoablation set by Callstrom et al. in 2013, what was the freeze-thaw cycle used and what were the outcomes? | The freeze-passive thaw-freeze cycle was as follows: 10 minutes - 8 minutes - 10 minutes, respectively. Iceball coverage was monitored via CT imaging every 2–5 minutes to monitor coverage of the tumor and prevent ice extension over critical structures to be avoided.<br>Cryoablation therapies improved the pain level of 49% of patients by a 2-point mean reduction in worst pain within one week of treatment. 75% of patients reported 90% or higher pain relief at some point in the follow-up period. Throughout the follow-up period of 24 weeks, only 14% of patients reported a pain level equal to or greater than their pain before the treatment. Although it did not reach statistical significance, the use of opioid analgesics decreased by 83% among patients who reported use prior to the procedure. |

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| In the study Dupuy et al. in 2010, what was the general treatment protocol for radiofrequency ablation of bone metastases and what were the overall results? | Ablation was performed at a current of 1100–2000 mA for a maximum of 4 minutes to ensure the intratumoral temperature exceeded 60 degrees Celsius. If the intratumoral temperature was below 60 degrees Celsius in this process, another 4-minutes treatment is performed at that position.<br>Radiofrequency ablation had a statistically significant improvement in pain relief, patient mood, pain intensity, and pain severity at one and three months. |

## Common Questions

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| What should patients expect in the normal post-procedure course after the therapeutic injection of anesthetic and steroid for epidural and spine nerve blocks? | Steroid pain relief will take several days to take effect. Therefore, a patient should expect return of symptoms once local anesthetic wears off in 6–24 hours until the steroids take their effect.<br>Response is highly variable. The mean duration of therapeutic spine injections is 3–6 months. The mean duration of therapeutic sacroiliac joint injections is approximately 10 months. |
| What is the role of ablation for malignant vertebral body compression fractures? | Ablation of vertebral metastasis provides pain palliation due to denervation of the periosteal nerves and also aids in locoregional tumor control to decrease the progression of disease. |

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# Part VIII
# Vascular Emergencies

# Chapter 46
# Trauma Embolization

**Justin J. Guan**

## Evaluating Patient

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| In the setting of trauma, what should always be evaluated and stabilized before undertaking further management? | First evaluate and stabilize the patient's ABCs: airway, breathing, and circulation. A comprehensive physical examination, followed by directed imaging, will then dictate further treatment and management. |

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| What imaging evaluation is used to screen for intra-abdominal hemorrhage? | FAST (Focused Assessment with Sonography for Trauma) Exam. This exam is safe and noninvasive, can be performed at the bedside and incorporated into the primary and secondary trauma survey, can be repeated serially, and can avoid the need CT scan and diagnostic peritoneal lavage due to high specificity for the detection of free fluid. The areas examined are:<br>Right upper quadrant (Morrison's pouch).<br>Left upper quadrant (left perisplenic space).<br>Pelvis axial and transverse views (pouch of Douglas).<br>Subxiphoid heart view (pericardial space).<br>Additional views obtained in the E-FAST exam include right anterior longitudinal chest view, left anterior longitudinal chest view, and longitudinal view of the IVC (significant, >50% collapse of the IVC in response to respiratory variation is a sign of hemodynamic instability). |
| Which imaging modality is most critical in evaluating for active internal hemorrhage? | Contrast-enhanced CT. Multiphase CTA is most ideal to localize bleeding and to demonstrate active extravasation, as well as differentiate arterial extravasation from pseudoaneurysm. |

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| In the setting of organ injury with active hemorrhage, what determines whether a patient will undergo surgical or nonoperative (endovascular or conservative) management? | Hemodynamic stability. Patients with intra-abdominal trauma who are hemodynamically unstable should proceed to surgery, whereas patients who are stable can undergo angiography and embolization. |
| In the setting of pelvic or extremity trauma, when is angiography and embolization indicated? | Patients with suspected ongoing arterial bleeding who are hemodynamically unstable and do not respond to fluid resuscitation are indicated for pelvic/extremity arteriography and embolization. Unlike in intra-abdominal bleeds where hemodynamic instability generally necessitates surgery, the anatomic complexities of the pelvis and extremities increase the difficulty of achieving hemostasis through surgery. |

## High Yield History

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| What are vital components of a patient's history in the setting of trauma? | Mechanism of injury (blunt or penetrating, type of weapon or missile), location of injury, environmental factors, and time of occurrence<br>Presenting Glasgow Coma Score (GCS)<br>Knowledge of all imaging findings and resuscitation efforts including amount of fluids, pressors, and transfusions administered |

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| What are vital components of physical exam in the setting of trauma? | Document any deformities, swelling, hematomas and evaluate for any change over time.<br>Detailed neurologic exam.<br>Cardiovascular exam, including pulse and BP. |
| List the "hard signs" of arterial injury in extremity trauma. What management approach do these signs generally portend? | Hard signs of arterial injury include: visible external arterial hemorrhage, rapidly expanding or pulsatile hematoma, palpable thrill or audible bruit, or obvious arterial occlusion on exam such as findings of pulselessness, pallor, paresthesia, pain, paralysis, or pokilothermia, especially after the reduction of dislocation or realignment of fracture. These findings generally require immediate surgical management. |
| List the "soft signs" of arterial injury in extremity trauma. What management approach do these signs generally portend? | Soft signs of arterial injury include: history of arterial bleeding at scene of injury, proximity of major artery(ies) to penetrating or blunt trauma, diminished unilateral distal pulse, small or nonpulsatile hematoma, neurologic deficit, ankle-brachial index <0.9, or abnormal waveform on Doppler ultrasound. In the presence of these findings, one may consider following with arteriogram or serial examinations. |
| In the setting of extremity trauma, what are some objective measurements that can be used to evaluate for adequate perfusion to the distal extremities? | Distal pulses, ankle-brachial index (ABI), wrist-brachial index (WBI). |

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| What are the general risk factors for embolization failure? | Predictive factors for the failure of non-operative management include high severity of injury and underlying, pre-existing disease, or the injury of the organ in question. |
| What is the recanalization time of Gelfoam, and why is this knowledge useful? | Gelfoam is broken down by the body and thus recanalizes in 4–6 weeks, making it a temporary embolic agent. Temporary agents provide short-term occlusion of vessels that will likely heal once hemostasis is achieved, for instance in cases of emergent GI bleeds, splenic bleeds, or uterine bleeds. Gelfoam can also be used as an adjunct to permanent embolic agents to help achieve thrombosis. A downside of temporary agents is that if the material breaks down before the vessel(s) can heal, the patient may rebleed. An advantage of temporary agents like Gelfoam is that once the agent recanalizes, access through the embolized vessel(s) may still be possible, whereas after using permanent agents like coils, future access will not be possible. |

## Indications/Contraindications

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| When is angiography and embolization indicated in the setting of trauma? | Angiography with embolization is generally indicated in cases of organ injuries where patients are hemodynamically stable but shows evidence of significant continued bleeding, such as dropping hemoglobin, continued need for fluid resuscitation and blood transfusions, or CT evidence of contrast extravasation. In cases of suspected pelvic or extremity arterial bleeds, embolization is indicated for patients who are hemodynamically unstable or require continued fluid resuscitation. |
| What are the key CT imaging features of active hemorrhage? How does this differ from a pseudoaneurysm? | Active hemorrhage is demonstrated on CT by extravasation of contrast, which appears as a linear, flame-shaped, or irregularly shaped hyperdensity that follows the density of contrast-enhanced arteries. The extravasation will typically have irregular borders. In cases of arterial bleeding, the extravasation will be seen on arterial phase and will quickly decrease in density on delayed phases. If present, a surrounding hematoma will also be seen to enlarge on delayed phase imaging. In comparison, a pseudoaneurysm typically appears as a sharply defined, round or oval area of hyperdensity that follows the density of contrast-enhanced arteries on arterial phase. It may also quickly decrease in density on delayed phase imaging; however, it will not be seen blending into an enlarging hematoma. |

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| Discuss in which circumstances temporary vs. permanent embolic agents are indicated. | Temporary: For short-term occlusion of vessel in cases where the vessel is expected to heal after damage, when a permanent treatment method is planned at a later time (such as for cases of temporary occlusion of bleeding splenic arteries before open splenectomy), or when need for repeat access to the site of interest in foreseen future.<br>Permanent: When long-term occlusion of vessel is preferred, such as in case of pseudoaneurysm or AVM, or when organ in question has rich collateral supply more distally so that recanalization for salvage of organ from ischemia is not required, such as in GI bleeds. |
| Discuss in which circumstances proximal vs. distal vessel embolization is indicated. | In general, proximal embolization is performed to relieve the arterial pressure head such as in blunt trauma to spleen or in times of severe hemodynamic emergency when time is critical. If an arterial injury is identified, it is ideal to embolize proximal and distal to the site of injury to avoid back filling. Distal embolization only may be performed when injury is supplied by a single end-vessel, or when multiple end-vessel territories are affected and the risk of ischemia is outweighed by control of bleeding. |
| What are general contraindications to arterial embolization for traumatic organ injuries? | Contraindications are generally relative and include hemodynamic instability, pre-existing organ disease or injury, multisystem trauma, and associated diaphragmatic or hollow viscous injury. |

## Relevant Anatomy

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| What is the dual blood supply to the liver and what proportion of liver blood supply do they each provide? | The portal vein supplies approximately 75% of the liver's blood supply, whereas the hepatic artery supplies approximately 25%. |
| What are the classic branches of the celiac trunk? | Splenic artery, left gastric artery, and common hepatic artery. |
| What are the common collaterals between the celiac trunk and superior mesenteric artery? | Gastroduodenal Artery – Branch of the common hepatic artery, anastomoses with the inferior pancreaticoduodenal artery via the anterior and posterior pancreaticoduodenal arcades<br>Dorsal Pancreatic Artery – Branch of splenic artery, anastomoses with the anterior and posterior pancreaticoduodenal arcades<br>Arc of Buhler – Branch of the celiac trunk, anastomoses with the superior mesenteric artery<br>Arc of Barkow – Connects the left and right gastroepiploic arteries |
| What are the common collaterals between the SMA and IMA? | Arc of Riolan – Continuous arterial arcade formed by connections between the proximal branches of the SMA and the proximal branches of the IMA. Compared to the Marginal Artery of Drummond, the Arc of Riolan runs more proximal to the mesenteric root.<br>Marginal Artery of Drummond – Continuous arterial arcade formed by connections between the distal branches of the SMA and the distal branches of the IMA. Compared to the Arc of Riolan, the Marginal Artery of Drummond runs more distal to the mesenteric root, along the inner border of the colon. |

## Relevant Materials

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| What is the difference between temporary and permanent embolic agents? Name two of each. | Temporary embolic agents are broken down by the body over a period of time and thus provide short-term occlusion of vessels, whereas permanent embolic agents are not broken down, thus preventing recanalization of the occluded vessels. Examples of temporary agents include Gelfoam (perhaps most common), autologous blood clot, and thrombin, while permanent agents include coils, plugs, and glues/polymers/polyvinyl alcohol. |
| Give examples of techniques/tools that reduce vascular bleeding through (1) intraluminal occlusion, (2) vasoconstriction, (3) vessel sclerosis/scarring, (4) patching or covering of holes within the vessel wall. | 1. Occlusion: Coils, plugs, particles, gelfoam<br>2. Vasoconstriction: Vasopressin, epinephrine<br>3. Sclerosis: Ethanol, sodium tetradecyl sulfate, n-butyl cyanoacrylate<br>4. Vessel patching/covering: Vascular stent, stent-graft |
| How are embolization coils labeled? Why is this important? | Coil wire diameter, coil wire length, and overall diameter taken up by coil when reformed.<br>The diameter of the coil wire must not be too small when compared to inner diameter of delivery catheter to prevent premature coil forming within the catheter and causing jams. Reformed coil diameter must be chosen carefully, as coils that are too small may embolize distally past the target region. Coils that are too big may not form in place and lead to insufficient vessel occlusion, or may get displaced proximally and preclude further access to the target artery. |

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| Define a "Gelfoam Sandwich." | Occlusive embolization technique using Gelfoam and another occlusive tool such as coils to cause permanent vessel occlusion. After the initial placement of coils, Gelfoam is injected to lodge within the coils. Additional coils are then again placed to cause complete, permanent vascular occlusion. |
| Explain the indication, contraindication, and dosage for intraluminal administration of vasopressin in gastrointestinal bleeding. | Vasopressin was often used in cases of bleeding to temporarily decrease the blood pressure or volume of bleed but when the preservation of flow is needed to prevent tissue ischemia or infarction. Such use of vasopressin is indicated in cases of gastrointestinal bleeding. Since vasopressin causes systemic vasoconstriction, it is contraindicated in patients with coronary artery disease. Initial administration dose is 0.2 U/min, with a maximum dose of 0.4 U/min. |

## General Step by Step

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| What is the most common approach for vascular access in cases of embolization for trauma or GI bleeding? | Common femoral artery access is the most common approach due to its technical ease, typically leading to faster time to access. Access from the side opposite to the injury or suspected site of bleeding is typically preferred. In certain cases where anatomic constraints limit access from the common femoral artery, for instance in cases of pelvic injuries requiring pelvic binders or arterial branch characteristics that necessitates special approach angles, radial artery access may be used instead. |

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| How do reverse-curve selective catheters differ from other selective catheters? What are the benefits to the reverse curve? | Reverse-curve catheters such as the Sos, Simmons, and Michelson catheters contain a primary curve distally that selects the branch artery, while a secondary curve more proximally helps to stabilize the catheter within the aorta. While the general advantage of reverse-curve catheters is that they help select more stenotic branches by applying extra down-force as the catheter is pulled down, these catheters are also preferred in selecting branches that make more acute angles from the aorta, such as the SMA and IMA. Non-reverse curve catheters like the Cobra make one primary curve and can be used to select branches that make less acute angles, such as the celiac and renal branches. |
| What category of catheters is then used to select smaller organ arterial branches? | Coaxial microcatheter. |

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| Discuss the pros and cons of proximal vessel embolization vs distal vessel embolization. | Distal vessel occlusion is often desired when there is a focal injury supplied by a single end-vessel. Distal occlusion can be achieved more easily with liquid embolic agents such as glue. Distal embolization has higher risk of tissue infarction due to lack of collateral vasculature.<br>In comparison, the occlusion of a proximal vessel is generally desired when a single vessel supplies a target area with multiple smaller injured branches that could not be easily accessed. In the case of the spleen, where a rich collateral supply is present along the splenic artery, proximal embolization is often preferred when simply reducing the arterial inflow pressure is enough to allow the spleen to achieve hemostasis on its own, as the collateral supply can prevent splenic infarction. The drawback to proximal embolization is loss of distal access, such that if significant bleeding persists, unless the area can be reached via a collateral pathway, further embolization will not be possible.<br>In certain cases of significant splenic bleeding, both distal and proximal splenic artery embolization may be employed, stabilizing focal areas of more significant bleeding via distal embolization, followed by proximal embolization to allow for hemostasis of the less significant remaining bleeds while preventing complete splenic infarction. |
| Define treatment failure. How long should patients be monitored as inpatients after non-operative management of organ injury? | Need for operative management after attempting non-operative management. Patients are monitored for at least 1–3 days to rule out persistent or recurrent bleeding or for any complications. |

## Complications

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| Name some general complications that can happen after arterial embolization. | Pseudoaneurysm at arterial puncture site, hematoma, dissection, thrombosis, organ infarction, infection with abscess formation, nontarget embolization, post-embolization syndrome. |
| Describe Post-Embolization Syndrome. | Pain, fever, and/or nausea that develop within 2-3 days after embolization procedure due to target organ necrosis. |
| What is the treatment and prognosis for post-embolization syndrome? | Treatment for post-embolization syndrome is supportive and usually include analgesics like acetaminophen or ibuprofen for pain and/or fever, oral anti-emetics such as ondansetron for nausea, and IV fluids for hydration as needed. The process is self-limited and will typically start to improve within 72 hours. |
| What are some specific complications after the embolization of liver laceration? What are risk factors for developing these complications? | Complications include nontarget embolization to gallbladder, hepatic necrosis, infection with abscess formation, bile leak or biloma formation, and post-embolization syndrome. Risk factors for developing these include high-grade liver injury and/or increased transfusion requirements. |
| What are some specific clinical sequalae, which may be experienced after embolization of kidney laceration? | Important sequalae to be aware of include nontarget embolization, decreased renal function, infection with abscess formation, and post-embolization syndrome. |

## Landmark Research

Padia SA et al. Society of Interventional Radiology Position Statement on Endovascular Intervention for Trauma. JVIR. 2020; 31(3): 363–369.

- Most of the data in trauma management is weak level of evidence. More emphasis is placed on assessing the strength of evidence by balancing benefits and risks. Strong recommendation – benefits of an intervention outweigh the risks. Weak recommendation – benefits and risks closely balanced.
- Catheterization in the traumatic setting can be much more difficult because the vasculature may be constricted as a result of significant blood loss or surrounding hematoma.
  - Operators should have significant experience with small vessel embolization, particularly in the elective setting.
  - Operative experience, experience with nonvascular intervention, or experience with large vessel intervention (aortic repair) is inadequate to perform small vessel catheterization and embolization in the setting of trauma, specifically liver, kidney, or pelvis.
  - Similarly, endovascular repair of the aorta should be done by an operator who has significant experience with endovascular aortic reconstruction in the elective setting.
- Currently no consensus whether to proceed directly to angiography in the pelvic trauma patient in hemodynamically stable condition with active contrast agent extravasation on CT.
  - Recommendation: Embolization for pelvic trauma should be first-line therapy and the standard of care over surgery (level of evidence, D; strength of recommendation, strong).
- There has been a paradigm shift in liver trauma, with nonoperative management becoming the treatment of choice

in a majority of patients with blunt hepatic injury who are in hemodynamically stable condition. This has resulted in decreased abdominal infections, decreased transfusions, and decreased lengths of hospital stay.

  - Recommendation: Nonoperative management should be the treatment of choice in patients with blunt hepatic injury who are in hemodynamically stable condition, with embolization to be considered in cases of ongoing bleeding, identification of an arterial source of bleeding on imaging, or suspicion of a persistent source of arterial bleeding despite operative intervention.

- Splenic embolization has shown high rates of success in preventing splenectomy; however, this may result from selection bias because low-grade injuries were included in some early reported series.

  - Recommendation: Splenic artery embolization should be considered for patients in hemodynamically stable condition with grade IV/V blunt splenic trauma (level of evidence, D; strength of recommendation: moderate).
  - Recommendation: Embolization should be considered in patients in hemodynamically stable condition with any grade injury who have imaging or clinical evidence of ongoing splenic hemorrhage (level of evidence, D; strength of recommendation, strong).

DuBose JJ, Savage SA, Fabian TC, et al. The American Association for the Surgery of Trauma PROspective Observational Vascular Injury Treatment (PROOVIT) registry: multicenter data on modern vascular injury diagnosis, management, and outcomes. J Trauma Acute Care Surg. 2015; 78(2)215–222.

- First longitudinal multicenter registry designed to evaluate the management and long-term outcomes of modern vascular injury.
- Endovascular management of vascular injuries have increased almost 30-fold in frequency from the early 1990s

to the early 2000s, from 0.3% to 9.0%, respectively; This increase was most noteworthy and dramatic among blunt injuries and specifically those to the internal iliac artery (8.0% to 40.3%), thoracic aorta (0.5% to 21.9%), and common/external iliac arteries (0.4% to 20.4%).

- According to the PROOVIT Registry:
  - In thoracic aortic trauma, the most common initial management method was non-operative (63.8%), followed by endovascular repair (41%), then open surgery (5.1%).
  - In abdominal trauma, including injuries to the abdominal aorta, celiac artery, common hepatic artery, and superior mesenteric artery, the most common initial management method was non-operative (50–75%), followed by endovascular repair (25–50%), then open surgery (0%).
  - In renal arterial injuries, most common initial management method was open surgery (44.4%), followed by non-operative (22.2%%), then endovascular repair (11.1%).
  - In pelvic trauma (common, external, or internal iliac arteries), most common initial management method was non-operative (50%), followed by endovascular repair and open surgery (both ~30% each).
  - In lower extremity trauma (femoral, popliteal, tibial, peroneal arteries), the most common initial management method was more or less tied between open surgery (14.3–61.1%) and non-operative (36.1–85.7%), followed by endovascular repair (0–3.5%).
  - In upper extremity trauma (axillary through radial/ulnar arteries), most common initial management method was open surgery (37.5–73.8%), followed by non-operative management (23.8–50%), then endovascular repair (0–12.5%).

Miller P, Chang M, Hoth J, et al. Prospective trial of angiography and embolization for all grade III to V blunt splenic

injuries: nonoperative management success rate is significantly improved. J Am Coll Surg. 2014; 218(4)644–648.

- The use of angiography and embolization improves the success rate of non-operative management for all-grade (I-V) splenic injury.
- The use of angiography and embolization, regardless of active extravasation on pre-procedural CT, improves success rate of non-operative management for high-grade (III-VI) splenic injury, (5% failure rate vs 31% failure rate when angiography and embolization was not routinely performed, $p = 0.02$).

Velmahos GC, Toutouzas KG, et al. A prospective study on the safety and efficacy of angiography embolization for pelvic and visceral injuries. J Trauma Acute Care Surg. 2002; 53(2)303–308.

- In patients with traumatic injuries to the pelvis and peritoneum, angiographic embolization is successful in controlling hemorrhage in 93% of patients who have angiographically proven bleeding. Embolization success is 95% if both patients with angiographically proven bleeding and patients with only indirect signs of vascular injury or hemodynamic instability are considered. Repeat embolization was successful in controlling bleeding in 75% of patients who failed initial embolization, raising the overall embolization success to 98%.
- A significant complication rate of angiographic embolization is 6%, with mechanisms comprised of organ necrosis around the site of injury (3%), splenic artery injury (1%), femoral artery occlusion at access site (1%), and AKI (1%). A minor complication of access site hematoma occurred in 3% of patients.
- Independent predictive factors for the presence of extravasation on angiography include age >55 years, the absence of long-bone fracture, and emergent angiography; Probability is 95% when all three factors are present and 18% when all three are absent.

## Common Questions

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| What are the top 5 most commonly injured abdominal organs in trauma (in order of frequency)? | 1. Spleen<br>2. Liver<br>3. Kidneys<br>4. Small bowel/mesentery<br>5. Bladder |
| Describe the AAST Liver Injury Grading Scale and summarize the properties of each grade. | Grade I<br>Hematoma: Subcapsular, <10% surface area<br>Laceration: Capsular tear, <1 cm parenchymal depth<br>Grade II<br>Hematoma: Subcapsular, 10–50% surface area; intraparenchymal, <10 cm diameter<br>Laceration: Capsular tear 1–3 cm parenchymal depth, <10 cm length<br>Grade III<br>Hematoma: Subcapsular, >50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal, >10 cm or expanding<br>Laceration: Capsular tear >3 cm parenchymal depth<br>Grade IV<br>Laceration: Parenchymal disruption involving 25–75% hepatic lobe or involves segments 1–3<br>Grade V<br>Laceration: Parenchymal disruption involving >75% of hepatic lobe or involves > segments 3 (within one lobe)<br>Vascular: Juxtahepatic venous injuries (retrohepatic vena cava / central major hepatic veins)<br>Grade VI<br>Vascular: Hepatic avulsion |

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| Describe the AAST Kidney Injury Grading Scale and summarize the properties of each grade. | Grade I<br>Contusion: Microscopic or gross hematuria, urologic studies normal<br>Hematoma: Subcapsular, nonexpanding without parenchymal laceration<br>Grade II<br>Hematoma: Nonexpanding perirenal hematoma confirmed to renal retroperitoneum<br>Laceration: <1.0 cm parenchymal depth of renal cortex without urinary extravasation<br>Grade III<br>Laceration: >1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravasation<br>Grade IV<br>Laceration: Parenchymal laceration extending through renal cortex, medulla, and collecting system<br>Vascular: Main renal artery or vein injury with contained hemorrhage<br>Grade V<br>Laceration: Completely shattered kidney<br>Vascular: Avulsion of renal hilum that devascularizes the kidney |
| In which cases should antibiotic prophylaxis be considered? What are possible choices? | Although antibiotic prophylaxis is not necessary in most cases of vascular embolization, cases in which antibiotics should be considered include patients who are neutropenic or are asplenic. Coverage should include skin flora, with options including cefazolin, clindamycin, and vancomycin. |

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# Chapter 47
# Spleen

**Justin J. Guan**

## Evaluating the Patient

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| What are the primary clinical manifestations of splenic injury? | Splenic hemorrhage, which, depending on severity, may lead to tachycardia and hypotension. Splenic infarction secondary to hemorrhage may manifest as pain. |
| What is the ideal imaging exam used to evaluate for splenic injury in the setting of trauma (given the FAST exam was already performed as indicated by primary/secondary survey)? | CT with IV contrast (CT angiography). |

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| Describe the AAST Spleen Injury Grading Scale. What are the main purposes of the grading scale? | The AAST splenic injury grading scale is a CT-based splenic injury scale developed to categorize splenic injury after trauma and help guide management. Higher-grade injuries (AAST grade III and higher) more often require surgical intervention, whereas lower-grade injuries are typically managed non-operatively. However, such image-based grading systems have been found to be poor predictors of patient outcome and eventual success of non-operative management. |

## *AAST Splenic Injury Scale*

Grade I
- Hematoma: Subcapsular, 10% surface area
- Laceration: Capsular tear, 1 cm parenchymal depth

Grade II
- Hematoma: Subcapsular, 10% to 50% surface area; intraparenchymal, 5 cm in diameter
- Laceration: Capsular tear, 1 to 3 cm parenchymal depth that does not involve a trabecular vessel

Grade III
- Hematoma: Subcapsular, 50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma 5 cm or expanding
- Laceration: 3 cm parenchymal depth or involving trabecular vessels

Grade IV
- Any injury in the presence of a splenic vascular injury or active bleeding confined within splenic capsule

- Parenchymal laceration involving segmental or hilar vessels producing >25% devascularization

Grade V
- Any injury in the presence of splenic vascular injury with active bleeding extending beyond the spleen into the peritoneum

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| How was the American Association for the Surgery of Trauma (AAST) organ system grading to define the severity of splenic injury revised in 2018? | To reflect data demonstrating that vascular injuries reduce the success rate of nonoperative management. Identification of pseudoaneurysms and active extravasation are now important parts of determining the injury grade, with the 2018 update classifying these as grade IV or V. |
| What is the current success rate of non-operative management after splenic injuries? Why is splenic preservation preferred? | The success rate of nonsurgical therapy varies between 80 and 90%, thus identifying cases that require surgical or angiographic interventions is critical. Splenic preservation after trauma serves as the aim of treatment given important immunological functions of the spleen. |
| What imaging characteristic(s) may predict the failure of nonsurgical management? | Higher volume of hemoperitoneum and presence of active and/or contained vascular injuries, such as contrast blush, pseudoaneurysms, and arteriovenous fistulae) are risk factors for failure of nonoperative management. |

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| Describe the Western Trauma Association Algorithm for the management of splenic injury patients who are hemodynamically stable. | Step 1:<br>The patient undergoes CTA.<br>Step 2:<br>If splenic injury is diagnosed with blush or pseudoaneurysm, perform endovascular embolization and admit to ICU.<br>If splenic injury is diagnosed however without blush or pseudoaneurysm, determine injury grade: Grade I/II – Admit to step-down unit for observation. Grade III-V – Admit to ICU for observation and medical management.<br>Step 3:<br>If the patient develops hemodynamic instability or peritonitis, perform laparotomy.<br>If the patient remains hemodynamically stable but Hgb drops by >/= 4, perform laparotomy or embolization. |

## High Yield History

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| What is the most commonly injured organ in the setting of trauma? | Spleen. |
| What is the most common cause of preventable death in trauma patients? | Overlooked splenic injury. |
| What proportion of patients have delayed splenic rupture requiring intervention after initially presenting with low-grade (grades I and II) splenic injury? | Approximately one-third of patients. |

## Indications/Contraindications

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| What has been the conventional treatment of choice for severe (Grade III-V) splenic injury? | Laparotomy with splenectomy or splenorrhaphy (surgical removal of splenic pseudoaneurysm). |
| What are the current indications for operative versus non-operative management (including splenic artery embolization) for splenic injuries? | All patients who are hemodynamically unstable undergo laparotomy with splenectomy or splenorrhaphy.<br>Non-operative management is indicated for patients who are hemodynamically stable. In this group, splenic artery embolization is performed when the patient is found to have ongoing splenic bleeding and the spleen is still viable.<br>Moreover, splenic tissue preservation is desirable in children, in whom the spleen still performs important immunologic functions. |
| What are the contraindications for splenic artery embolization? | Absolute contraindication: hemodynamic instability. Splenic artery embolization in patients who establish transient hemodynamic stability after resuscitation can lead to favorable prognosis if embolization is performed early.<br>Relative contraindications: pre-existing splenic disease, multisystem trauma, associated diaphragmatic rupture, or bowel injury. |

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| Discuss the indications for selective, distal splenic artery embolization versus main splenic artery embolization. | Selective, more distal splenic artery embolization is performed to stop focal areas of splenic hemorrhage. Such approach preserves a larger amount of splenic tissue but is theoretically more likely to cause focal splenic infarction.<br>Main splenic artery embolization reduces splenic hemorrhage but reducing the total amount of blood flowing into the spleen. Complete splenic infarction does not occur due to the spleen's collateral blood supply. |
| Must patients receive Pneumococcus, H. influenzae, or N. meningitidis vaccination after splenic artery embolization? | Splenic tissue is usually preserved after splenic artery embolization. With the currently available evidence for residual splenic function after proximal and distal splenic embolization, routine vaccination is not indicated. |

## Relevant Anatomy

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| What major aortic branch vessel does the splenic artery arise from? | Celiac Trunk. |
| List the major branches of the splenic artery. | Dorsal pancreatic artery, posterior gastric artery, greater pancreatic artery, left gastroepiploic artery, and short gastric branches and unnamed branches to the pancreatic tail. |
| What major branch has variable origin from the splenic artery? | Posterior gastric artery (arises from splenic artery <50% of time). |

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| Why is the splenic tissue typically not lost even after proximal splenic artery embolization? | The spleen has rich collateral supplies from the splenic artery branches, including the short gastric, left gastroepiploic branches, and smaller unnamed branches. |
| What are some possible anatomic variations of the spleen? | Accessory spleen or splenules, splenosis, polysplenia, wandering spleen, and asplenia. |

## Relevant Materials

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| What materials are typically used for proximal main splenic artery embolization? | Coils or plugs. |
| What materials are typically used for selective distal splenic artery embolization? | Coils, Gelfoam, glue or other liquid embolics, and microparticles. |
| Is antibiotic prophylaxis indicated for splenic artery embolization? What are possible regimens? | Routine antibiotics covering skin flora should be administered during splenic artery embolization, especially if more than 70% of the spleen is to be embolized. Although no consensus is established for 1st-line agent, some recommended regimens include IV gentamicin 10 mg/kg/day, IV cefoxitin 100 mg/kg/day, or IV amoxicillin-clavulanate 3 g/day, with the first dose starting 2 hours before procedure and continuing for 5 days post-procedure. |
| What are the sedation options for splenic artery embolization? | Either IV conscious sedation or general anesthesia depending on the availability of anesthesia resources and the patient's clinical status. |

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| Is routine follow-up CT imaging recommended after discharge? | Follow-up CT imaging after discharge is not routinely recommended. |

## General Step by Step

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| Describe the different possible approaches for splenic artery embolization and their respective risks and benefits. | SAE can be performed via (1) proximal occlusion between the dorsal pancreatic artery and terminal splenic artery branches, (2) distal occlusion at the involved segmental splenic arterial branch, or (3) a combination of both.<br>Proximal SAE reduces bleeding by decreasing splenic arterial pressure but prevents splenic infarction by allowing for reconstitution of the distal splenic artery branches via collaterals. This approach is used in cases of splenic injury where no focal splenic branch vessel injury can be identified on angiography.<br>Distal SAE can be performed when injury involves one or a limited number of focal splenic branch vessel territories and allows for targeted vascular occlusion. Since this approach tends to exclude collateral supplies, there is a higher risk of splenic infarction. |
| How long are patients monitored after embolization? | Patients are monitored as inpatients for at least 1–3 days. |

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| What may reduce morbidity and mortality associated with delayed splenic rupture after non-operative management of splenic injuries? | Routine follow-up CT imaging 48 hours after nonoperative management. |
| What are the recommendations for return to normal daily activities and return to sports? | Return to normal daily activities 2–3 months after management, may be longer in higher grade injuries<br>Return to sports after 3 months<br>No clear consensus on when to return to contact sports in patients with high-grade splenic injury |

## Complications

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| List the possible complications after splenic artery embolization. | Splenic infarction leading to infection/abscess, nontarget embolization of pancreas causing infarction, access-site pseudoaneurysm, arterial dissection, hematoma, thrombosis, and post-embolization syndrome. |
| What are the clinical manifestations of post-embolization syndrome? | Localized or generalized pain, fever, nausea/vomiting, and leukocytosis that develop within 3 days after embolization procedure |
| What is the treatment and prognosis for post-embolization syndrome? | Treatment is supportive; process is self-limited. |
| What are some manifestations of splenic rupture? | Elevation of left hemidiaphragm, left lower lobe atelectasis, and left pleural effusion |

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| When does delayed splenic rupture typically occur? | 4–8 days after nonoperative management. |

## Landmark Research

Miller P, Chang M, Hoth J, et al. Prospective trial of angiography and embolization for all grade III to V blunt splenic injuries: nonoperative management success rate is significantly improved. J Am Coll Surg. 2014; 218(4)644–648.

- The use of angiography and embolization improves the success rate of non-operative management for all-grade (I-V) splenic injury.
- The use of angiography and embolization, regardless of active extravasation on pre-procedural CT, improve success rate of non-operative management for high-grade (III-VI) splenic injury, (5% failure rate vs 31% failure rate when angiography and embolization was not routinely performed, $p = 0.02$).

Sabe AA, Claridge JA, Rosenburg DI, Lie K, Malangoni MA. The effects of splenic artery embolization on nonoperative management of blunt splenic injury: a 16-year experience. J Trauma. 2009; 67:565–572.

- Initial non-operative management for blunt splenic injury has significantly increased compared to initial operative management over the last two decades with relatively stable severity of splenic injury.
- The use of splenic artery embolization and success of non-operative management for blunt splenic injury has significantly increased over the last two decades.
- The use of splenic artery embolization improves the success of non-operative management and leads to reduced mortality, increased overall splenic salvage and shorter hospital stays, although incorporation of a defined criteria for initial splenic arterial embolization (including the pres-

ence of extravasation or pseudoaneurysm on CT, grade 3 injuries with large hemoperitoneum, or grade 4 injuries in the setting of hemodynamic stability) did not improve these outcomes compared to discretionary use of splenic artery embolization based on clinical and CT findings.

Wahl WL, Ahrns KS, Chen S, Hemmila MR, Rowe SA, Arbabi S. Blunt splenic injury: Operation versus angiographic embolization. Surgery. 2004; 136:891–9.

- Higher injury severity score, lower systolic blood pressure before intervention, lower ABG pH, GCS < 9, and increased units of PRBC infused before intervention were associated with increased mortality, regardless of surgical or embolization intervention.
- Higher ISS, lower pre-treatment SBP, higher number of pre-treatment transfusions of PRBCs, and lower ABG pH were best predictors for the need of operative intervention.
- Surgical intervention was associated with higher rates of intra-abdominal complications, such as development of intra-abdominal abscess, peritoneal fluid requiring aspiration or drainage, pancreatic leaks, abdominal compartment syndrome, wound dehiscence, and small bowel obstruction, as well as an increased number of subsequent imaging studies to evaluate for intra-abdominal complications.
- After adjusting for GCS, ISS, a number of pretreatment transfusions, spleen AIS, and age, there was no different in overall treatment costs between patients who underwent surgical or embolization intervention.

## Common Questions

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| Why are patients in unstable condition managed operatively? | The need to rapidly control bleeding, which may not be from major arterial sources. |

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| What is the overall success rate of splenic artery embolization in preventing splenectomy for high-grade splenic injuries? | Up to 90%. There appears to be no significant difference in treatment failure regardless of proximal or distal splenic artery embolization. |
| What is the most important long-term complication after splenectomy? | Infection by encapsulated organisms – *S. pneumo*, *H. flu*, *N. meningitidis*. |
| What is usually done to prevent infection by encapsulated organisms after splenectomy? | Vaccination against encapsulated organisms. |
| Is infection by encapsulated organisms a risk after splenic artery embolization? Is vaccination against these organisms required? | Infection by encapsulated organisms is not a typical risk after splenic artery embolization as splenic tissue is usually preserved. Therefore, vaccination against encapsulated organisms is generally not required. |

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# Chapter 48
# Pelvis

**Justin J. Guan**

## Evaluating Patient

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| What should initial evaluation and management of pelvic trauma focus on? | Before arriving at the hospital, initial management of extremity trauma should focus on control of bleeding and pelvic fixation/splinting of obvious fractures.<br>Upon presentation to the hospital, management should focus on the evaluation and stabilization of the ABCs (airway, breathing, circulation) and resuscitation efforts as necessary, including fluids/transfusions and pressors.<br>Comprehensive physical examination and focused imaging evaluations guide further management. |

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| What are key parts of the history and physical exam? | History – focus on mechanism of injury, timing, and GCS<br>Physical exam – should include evaluation for hematomas and areas of active bleeding, detailed neurologic examination, and assessment of distal pulses |
| What are some signs of vascular injury on physical exam? | Hard signs – expanding pulsatile hematoma, bruit/thrill over wound, absent distal pulses, distal ischemic changes (six Ps: pain, pallor, pulselessness, poikilothermia, paresthesia, paralysis)<br>Soft signs – nonexpanding hematoma, peripheral neural deficits, history of severe bleeding at the time of injury, unexplained hypotension, significant bony injury including significant fracture displacement, and penetrating wound(s) |
| What imaging exam can be used to help localize active bleeding while evaluating for other internal injuries before angiography? | CT pelvis with IV contrast – can help identify the location of active bleed (contrast extravasation), as well as evaluate for hematomas, fractures, and other injuries to the bowel and bladder in order to guide selective angiography<br>CT angiogram of extremities – can better characterize fracture and neurovascular involvement to the pelvis and extremities |
| What additional imaging exams can help identify internal injuries? | FAST (focused abdominal sonography for trauma) exam and plain films. |
| What constitutes a positive finding on FAST exam? What does this signify? | Finding free fluid within any of the evaluated spaces raises concern for hemorrhage. |

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| Which patients with identified pelvic ring injuries should be considered for angiography? | Stable patients with *clinically* significant active arterial extravasation identified on CT abdomen/pelvis. Currently, no consensus based on the presence of active arterial extravasation alone. Angiography findings can be negative despite contrast agent extravasation on CT, and, on the contrary, angiography findings can be positive when CT has demonstrated no contrast agent extravasation.<br>Unstable patients with negative FAST and diagnostic peritoneal lavage (DPL), no other sources of bleeding identified and any of the following:<br>Hypotensive (systolic BP < 90 mmHg, >1 event)<br>Persistent tachycardia (HR > 100 beats/min)<br>BP maintained only with continuous blood transfusion<br>Significant drop in Hct/Hgb (> 6% Hct, >2 Hgb) |
| What are the iliopectineal and ilioischial lines? What do disruptions of these lines signify? | Iliopectineal line makes up the border of the iliopubic eminence, or the inner border of the pelvic brim on an AP pelvis radiograph. This line should be continuous, and any discontinuity raises concern for an anterior column fracture of the pelvis.<br>The ilioischial line is the projection created by the quadrilateral plate of the acetabulum on AP pelvis radiograph, lying just lateral to the iliopectineal line. This line should be continuous, and any discontinuity raises concern for a posterior column fracture of the pelvis. |

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| What makes older patients more prone to significant arterial bleeding in the setting of pelvic fracture? How does this affect imaging evaluation in these patients? | Patients older than 60 years have arterial calcifications that hinder effective vasoconstriction in the setting of vascular injury and thus are more prone to active bleeding. |

## High Yield History

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| What are the four categories/mechanisms of pelvic fractures? | Lateral compression, anterior-posterior compression, vertical shear, and combined. |
| Give examples of the different pelvic fracture mechanisms. | Lateral compression – typically car accidents where patients are T-boned<br>Anteroposterior compression (open-book fractures) – front-end car collisions or other high-force impact<br>Vertical shear – typically after falls from height |

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| How do fracture patterns predict vascular injury? | The superior gluteal and internal pudendal arteries are the most commonly injured arteries in pelvic fractures, while the deep circumflex iliac and inferior epigastric arteries are more rarely injured.<br>Published fracture patterns that tend to predict a high likelihood for arterial injury are vertical shear-type fracture pattern, combined mechanisms, and high-grade anterior/posterior and lateral compression fractures.<br>Common associations:<br>Anterosuperior compression – associated with injuries of superior gluteal and internal pudendal arteries<br>Lateral compression – anterior division internal iliac artery injury<br>Pubic rami and open-book fractures – injuries of internal or external pudendal arteries<br>Acetabular fracture – superior gluteal arteries |
| Approximately what percentage of pelvic fractures are from lateral compression versus other mechanism(s)? | 65% of pelvic fractures are from lateral compression, while 35% are from non-lateral compression mechanisms. |

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| How can bleeding from most pelvic fractures be initially stabilized? What percentage of bleed cases from pelvic injuries can be stabilized in this manner? | Pelvic fixation devices can stabilize 99% of cases from lateral compression pelvic injuries and up to 80% of pelvic injuries from non-lateral compression mechanisms. 18–22% of cases from anteroposterior, vertical shear, and combined force injuries lead to unstable injuries with bleeding unresponsive to pelvic fixation. |
| What are the categories of acetabular fractures? | Posterior column, anterior column, or transverse. |

## Indications/Contraindications

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| What findings on clinical evaluation dictates immediate surgical exploration and repair? | Hemodynamic instability despite resuscitation, hemodynamically unstable patient with imaging findings indicating intraperitoneal hemorrhage, and hard signs of vascular injury. |
| What are the surgical treatment options of vessel injury? | Primary surgical repair (suturing of laceration, end-to-end anastomosis of transection)<br>Small vein patch over laceration<br>Synthetic or reverse venous graft to repair damaged vessels or reapproximate retracted vessels<br>Ligation or shunting with delayed definitive repair after stabilization of patient |

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| When is pelvic arteriography and embolization indicated? | Patients who remain hemodynamically unstable or have transfusion requirement of more than 4–6 units of PRBCs in 24 hrs, after pelvic fixation, with injuries isolated to the pelvis or pelvic retroperitoneum (intraabdominal injuries are ruled out or repaired via laparotomy) should undergo emergent pelvic angiography and embolization.<br>Hemodynamically unstable patients with pelvic arterial bleeding suspected following exploratory laparotomy for abdominal injuries.<br>Patients who are hemodynamically stable with soft signs of vascular injury or extravasation documented on CT exam can proceed directly to pelvic angiography. |
| Should pelvic retroperitoneal bleeds found on imaging or during laparotomy be repaired surgically? | No, retroperitoneal bleeds should not be repaired surgically as surgical repair of the retroperitoneum is technically difficult and opening the retroperitoneum releases the tamponade of the hematoma. |
| What is the success rate of angiography and embolization in controlling pelvic and extremity bleeding? | Pelvic angiography and embolization have 85–97% success rate in controlling pelvic bleeding; 5–23% of patients may require repeat angiography.<br>Extremity angiography and embolization have 84–97% success rate in controlling extremity bleeding. |

## Relevant Anatomy

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| Name the typical branches of the posterior division of left internal iliac (hypogastric) artery. Which is typically the largest branch? | Iliolumbar artery<br>Lateral sacral artery<br>Superior gluteal artery<br>The superior gluteal artery is typically the largest branch. |
| Name the typical branches of the anterior division of left internal iliac (hypogastric) artery. How do the branches differ between males and females? | Vesicle artery (superior and inferior branches)<br>Obturator artery<br>Middle rectal artery<br>Internal pudendal artery<br>Inferior gluteal artery<br>Uterine artery (females)<br>Prostatic artery (males)<br>Females have the uterine artery (which branches into the uterine and vaginal arteries). Branches of the vaginal arteries may also originate from the inferior vesicle artery.<br>Males have the prostatic artery, which can arise as a separate branch from the anterior division of the internal iliac artery, as a branch from the obturator, superior vesicle, or inferior gluteal arteries, or from the internal pudendal artery.<br>In males, the internal pudendal artery branches into the perineal artery (which supplies the scrotum) and a common penile artery, which branches into the dorsal and deep penile branches. |

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| Which arterial branch often arises from the posterior wall of the abdominal aorta just proximal to the aortic bifurcation before coursing inferiorly down the midline to supply the sacrum and coccyx? Which arteries does it usually anastomose with? | Median sacral artery, often anastomoses with the iliolumbar and rectal arteries. |
| What arteries can often form collateral supply to the uterus apart from the uterine artery? | Ovarian, vaginal, vesicle, and unnamed branches from the broad ligament. |
| What arteries form collateral supply to the ovary apart from the ovarian artery? | Uterine arteries. |
| What are some common collateral arterial pathways within the pelvis? | Midline bleeding can be supplied by either/both internal iliac arteries; lateral pelvic bleeds can be supplied by the lumbar, iliac circumflex, deep femoral, as well as internal iliac branches. |

## Relevant Materials

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| What is the diagnostic modality of choice in evaluating bleeding patients prior to angiography? | CT with contrast (CT angiogram). |
| What methods of vascular occlusion can be employed to treat identified areas of arterial injury on angiogram? | Treatment can be performed using temporary agents, such as Gelfoam, or permanent agents, such as coils and/or particulate embolics. |

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| What are the indications of using each method? | A diffuse agent such as Gelfoam may be desired in cases of multiple scattered foci of extravasation, whereas micro-coils may be used for fistulas or pseudoaneurysms. |
| What are the dangers of using a diffuse agent such as Gelfoam or particles to treat vascular injuries? | Nontarget embolization or distal embolization causing extremity ischemia is more likely with materials that are smaller and more uniform in size, such as Gelfoam slurry or particle embolics. Thus, these materials are used less often for extremity embolization. |
| What size catheters are usually used for pelvic angiography studies? | 4-Fr or 5-Fr catheters |

## General Step by Step

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| What are the options for arterial access in pelvic angiography? | Femoral artery is usually accessed, and bilateral access may be required if multiple areas of pelvic bleeding or multiple collateral feeding arteries to the area of bleeding is suspected. Radial access may also be used depending on the case. |
| Where should the angiogram catheter be placed for initial angiography run? | Within the abdominal aorta, 2–3 cm proximal to the aortic bifurcation. |
| What is the typical range of contrast injection rate for pelvic angiography? | 6–8 cc/sec for 3 seconds. |

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| What should always be done after the occlusion of vascular injury to rule out continued bleeding from collateral blood supply? | Completion pelvic angiogram. This ideally includes a pelvic angiogram in the frontal projection, followed by selective left and right internal iliac angiograms, often with oblique views to help "open up" the branches of the internal iliac artery. |
| How can adequate extremity perfusion be evaluated after angiography and embolization? | Serial evaluation of extremity pulses should be performed. |

## Complications

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| What is the key complication associated with pelvic embolization? | Reflux of embolic material or antegrade flow into a clinically relevant branch vessel contributes to nontarget embolization, which is associated with ischemic complications. |
| What are the locations where emboli may lodge and cause extremity ischemia? | Though the occlusion of the superficial femoral artery or popliteal artery can cause ischemia, such cases are rare. Occlusions at branch vessels or small, distal branches are usually clinically silent. |
| Describe compartment syndrome. | An increase in muscle compartment pressure after revascularization, occurring as a result of edema and reperfusion injury after ischemic insult to the extremity, which may lead to vascular compression and tissue necrosis. |

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| How is compartment syndrome diagnosed? How can it be prevented? | Compartment syndrome is most often diagnosed clinically based on the classic "P"s: PAIN out of proportion to clinical examination or injury, usually with passive stretching or at rest, PARESTHESIA progressing to hypoesthesia and anesthesia, PARALYSIS, often a late findings due to prolonged nerve compression or irreversible muscle damage, PULSELESSNESS, also a late finding, and PALLOR, secondary to compromised arterial inflow. The affected extremity will often appear swollen and feel firm. Definitive diagnosis is made based on compartment pressure monitoring showing elevated pressures. Because compartment syndrome occurs secondary to rise in compartment pressure, such as from tissue swelling, bleeding, or reperfusion injury following prolonged ischemia, prevention of compartment syndrome in the setting of trauma requires high clinical suspicion, and close serial examinations to catch impending cases before they develop. If compartment syndrome is likely to develop, prophylactic fasciotomy can be performed to relieve compartment pressure. |
| How is compartment syndrome managed? | Surgical fasciotomy; as detailed above, close examination for compartment syndrome should be performed after revascularization procedures. |
| Define "Corona Mortis." Why is this important? | Corona mortis is a variant arterial branch that connects the obturator artery to the inferior epigastric artery, often running along the posterior aspect of the superior pubic ramus. This vessel can be the source of bleeding if lacerated from a pelvic ring fracture and thus should always be investigated during pelvic trauma involving the superior pubic ramus. |

## Landmark Research

Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma: WSES classification and guidelines. World J Emerg Surg. 2017; 12:5.

- Patients with pelvic fracture-related hemodynamic instability should always be considered for pre-peritoneal pelvic packing, especially in hospitals with no angiography service; direct preperitoneal packing is an effective surgical measure of early hemorrhage control in hypotensive patients with bleeding pelvic ring disruptions.
- CT-scan demonstrating arterial contrast extravasation in the pelvic and the presence of pelvic hematoma are the most important signs predictive of need for angioembolization.
- Elderly patients with pelvic fractures should be considered for pelvic angiography/angioembolization regardless of hemodynamic status.

Cullinane DC, Schiller HJ, Zielinski MD, et al. Eastern Association for the Surgery of Trauma practice management guidelines for hemorrhage in pelvic fracture – update and systematic review. J Trauma. 2011;71(6):1850–1868.

- The use of the pelvic orthotic device, such as a pelvic fixator device, reduces fracture displacement and pelvic volume after pelvic fractures; however, it does not seem to limit blood loss in patients with pelvic hemorrhage.
- Patients with pelvic fractures and signs of ongoing pelvic bleeding such as hemodynamic instability after nonpelvic sources of blood loss have been ruled out or, with arterial extravasation on CT despite hemodynamic status, should be considered for pelvic angiography and embolization.
- Although FAST has adequate specificity in patients with unstable vital signs and pelvic fracture to recommend laparotomy to control hemorrhage, it is not sensitive enough to exclude intraperitoneal bleeding in presence of pelvic fracture.

- In the hemodynamically stable patient with a pelvic fracture, CT abdomen/pelvis with IV contrast is recommended to evaluate for intra-abdominal bleeding, regardless of FAST results.

Ben-Menachem Y, Coldwell DM, Young JW, et al. Hemorrhage associated with pelvic fractures: causes, diagnosis, and emergent management. AJR Am J Roentgenol. 1991;157(5).

- The high mortality rate in patients with pelvic fractures is related directly and primarily to hemorrhage; some victims die because of intractable shock and coagulopathy, while others succumb to complications of hemorrhage, such as infected hematomas or renal/multiorgan failure.
- Arterial injuries are most prevalent in patients in whom the bony elements are fractured and ligamentous elements are torn: anteroposterior compression types II and III, lateral compression type III, vertical shear, and combined mechanical injuries; The most frequently injured arteries are the superior gluteal and internal pudendal arteries, associated with AP compression fractures.
- If a patient is hemodynamically unstable, an immediate arteriogram and embolization is of great benefit; even in cases in which an operation is necessary, the angiographer can accomplish almost instant hemodynamic stability by occluding the lower abdominal aorta with a balloon.

## Common Questions

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| Which is more common in pelvic trauma, arterial or venous injury? | Although less common, arterial injury is more frequently associated with hemodynamic instability than venous injury. Arterial source of hemorrhage in pelvic injury is identified in more than 70% of patients with no response to fluid resuscitation or transfusion. |

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| What is the likelihood of angiographically identifying active arterial hemorrhage in a patient demonstrating active contrast agent extravasation on contrast enhanced CT? | High with sensitivity ranging from 80% to 90% and specificity ranging from 85% to 98%. |
| What are reported rates of repeat angiography in patients with suspected ongoing or recurrent bleeding? | 0%–23%. In these patients, findings at angiography frequently demonstrate a new site of hemorrhage that was not treated or visualized on the initial study. The following findings are highly predictive of recurrent arterial hemorrhage:<br>Hypotension<br>Disruption of the pubic symphysis<br>Transfusion requirement of >2 U/h of packed red blood cells<br>More than 2 arterial injuries visualized on the initial pelvic angiogram |
| How can resolution of bleeding be confirmed clinically after the angiographic treatment of pelvic or extremity bleeding? | Serial hemoglobin/hematocrit (H/H); If H/H continues to downtrend, repeat angiogram and embolization may be indicated. |
| What arterial branches from the external iliac artery mark the transition from external iliac artery to common femoral artery? | The deep circumflex iliac artery arising laterally and the inferior epigastric artery arising medially. |

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| At which spinal vertebral level does the abdominal aorta bifurcate into the left and right common iliac arteries? | L4-5. |
| Approximately what percentages of pelvic fractures are isolated to the pelvic ring, isolated to the acetabulum, or involve both? | Pelvic ring only: about 60%<br>Acetabular involvement only: about 30%<br>Pelvic ring and acetabular involvement: about 10% |
| What imaging manifestations on pelvic angiogram suggest vascular injury? | Contrast extravasation, pseudoaneurysm, and large arteriovenous fistula. |

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# Chapter 49
# Bronchial Artery Embolization

**Justin J. Guan**

## Evaluating the Patient

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| What are important aspects of the clinical history during patient evaluation? | Frequency and severity of hemoptysis, any evidence of airway compromise, and information or history that may help determine the underlying etiology. |
| What are important components of the physical exam during patient evaluation? | Evaluate for signs of respiratory distress (tachypnea, tachycardia, auscultation of lungs for wheezing or decreased breath sounds) and hemodynamic instability (pulse, BP). |
| What are important laboratory values to consider during patient evaluation? | Hemoglobin/hematocrit to evaluate for degree of anemia<br>WBC and cultures to evaluate for infection<br>Coagulation profile and renal function before arteriogram and embolization |

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| What is the best noninvasive imaging modality for the evaluation of massive hemoptysis? | CT angiography – Can identify the etiology of hemoptysis and demonstrate bronchial artery anatomy, assisting in pre-procedural planning. |
| Can CTA usually confirm the site of bleeding and evaluate for laterality of involvement? Which invasive diagnostic studies can help evaluate for bleeding site and also be therapeutic? | CTA does not usually locate the exact site of bleeding, but it can lateralize the site of bleeding when the source is unilateral.<br>Fiber-optic bronchoscopy – Can help confirm bronchial etiology for hemoptysis and identify the laterality of involvement in up to 95% of cases. It can also treat the source of hemoptysis in some cases.<br>Arteriography and embolization – Both diagnostic and therapeutic; first-line therapy for most cases of massive hemoptysis; also indicated when bronchoscopy cannot adequately control ongoing bleeding. |
| What is the typical appearance of abnormal bronchial arteries that may suggest sites of bleeding? | One or more enlarged, hypertrophied, and tortuous vessel extending along the tracheobronchial tree into an extensive area of patchy hypervascularity; AV shunting or pseudoaneurysms may also be seen. Active contrast extravasation is not commonly seen. |

## High Yield History

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| Define massive hemoptysis. | Hemoptysis > 250 ml in volume within 24 hours. |

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| Define a major hemorrhagic hemoptysis event. | Three or more days of hemoptysis in a week, with each day totaling greater than or equal to 100 ml in volume. |
| What are the potential clinical results of continuing hemorrhage into the airways? What is the mortality rate with conservative management? | Hypovolemia and asphyxiation; this can lead to a mortality of 50–85% with conservative management. |
| What are common etiologies for massive hemoptysis? | Infections (Tb, Aspergillosis, chronic bacterial pneumonia)<br>Chronic lung diseases (CF, sarcoidosis, COPD, interstitial pneumonias)<br>Malignancy<br>Trauma |
| Massive hemoptysis is most commonly associated with the abnormality of which circulation of the lungs (bronchial or pulmonary)? | Systemic arteries that supply the bronchial tree – bronchial arteries, although pulmonary arterial system can cause massive hemoptysis, this is rare. |
| What characteristic of the bronchial airway system makes bronchial artery embolization an effective and safe intervention for controlling hemoptysis? | Occlusion of targeted bronchial arteries causes little or no ischemia of the bronchial airways while having a high success rate of stopping hemoptysis. This is because up to 95% of massive hemoptysis cases originate from the bronchial artery system, yet the bronchial system supplies less than 1% of blood flow to the lungs. More than 99% of the blood flow to the lungs is supplied by the pulmonary system. |

## Indications/Contraindications

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| What is the gold standard or first-line therapy for massive hemoptysis? | Bronchial arteriogram with embolization is now considered the gold standard treatment for massive hemoptysis, as most massive hemoptysis cases originate from the bronchial arterial system. However, most patients will have first undergone bronchoscopy given its benefits of obtaining an airway for oxygenation and its ability to both localize and treat the source of bleeding. |
| What are contraindications to bronchial artery embolization? | Non-bronchial artery source for bleeding, i.e., pulmonary artery<br>Contrast allergy<br>Inability to perform general endotracheal anesthesia (GETA) |
| Is shunting between the bronchial arteries and the pulmonary veins or arteries an absolute contraindication to embolization? | Shunting may be seen during angiography and is not an absolute contraindication, though it may require adjustment of technique. |

## Relevant Anatomy

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| The bronchial arteries most commonly arise from which levels of the thoracic aorta? | T3-T8 levels, with most arising from T5-T6 levels. The left bronchial arteries (typically two) most commonly arise from the descending thoracic aorta. |
| What structures do the bronchial arteries supply? | The trachea and major bronchial airways, esophagus, vagus nerve, visceral pleura, mediastinal lymph nodes, vasa vasorum of thoracic aorta, and pulmonary arteries |

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| Define orthotopic vs ectopic origins of the bronchial arteries. What are possible ectopic sites? | Orthotopic describes normal origins of the bronchial arteries from the descending thoracic aorta, while ectopic describes variant origins of the bronchial arteries. In at least 20% of patients, at least one of the bronchial arteries can arise from the subclavian artery, internal mammary artery, thyrocervical trunk, superior intercostals, pericardiophrenic and inferior phrenic arteries, abdominal aorta, or coronary arteries. |
| Which collateral arteries may hypertrophy and parasitize sites of bronchial arterial bleeding? | In the setting of prior embolization or chronic lung disease, parasitizing vessels may originate from the intercostal, inferior phrenic, internal thoracic arteries, or the costocervical and thyrocervical trunks. |
| Describe the Caldwell variations of the bronchial artery branching pattern. | Type I – Most common (40% of pts), single right intercostcobronchial trunk and two left bronchial arteries with separate origins<br>Type II – 20%, single right intercostcobronchial trunk and only one left bronchial artery<br>Type III – 20%, right intercostcobronchial trunk with additional right bronchial artery having separate origin, and two left bronchial arteries<br>Type IV – 10%, right intercostcobronchial trunk with additional right bronchial artery having separate origin, and one left bronchial artery |
| Can the bronchial arteries supply an anterior spinal artery? Why is this important? | Yes, the right intercostobronchial trunk (which gives rise to right-sided bronchial artery branches) can give rise to an anterior medullary artery that supplies the spinal cord through an anterior spinal artery. The anterior medullary branch characteristically forms a hairpin turn on angiogram. It is important to identify any spinal artery supply from the bronchial arteries to prevent inadvertent nontarget embolization of the anterior spinal artery, which can lead to paraplegia. |

## Relevant Materials

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| What is the key prerequisite for determining the use of general anesthesia versus conscious sedation when performing bronchial artery embolization? | Airway patency is vital; in some cases, a unilateral selective main stem bronchial intubation may be required. |
| Describe how an endobronchial blocker can be used to achieve selective unilateral bronchial intubation. | The endobronchial blocker is a device that can be inserted coaxially down the tracheal tube after tracheal intubation and into either the left or right mainstem bronchus. The balloon attached to the blocker is then insufflated, effectively blocking that bronchus and achieving unilateral intubation of the contralateral side. |
| What sized catheters are used to selectively catheterize bronchial arteries? | Selective catheterization of abnormal vessels is performed with 4-Fr or 5-Fr catheters. Superselective catheterization can be performed using 3-Fr or smaller microcatheters to select smaller, more distal, or tortuous bronchial arteries. |

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| Discuss the embolic agent(s) typically used for bronchial artery embolization. | Polyvinyl alcohol (PVA) particles and solid (tris-acryl gelatin, TAGM) microspheres are the most commonly used agents; coils provide more proximal occlusion compared to PVA or liquid embolizing agents and are thus used in cases of aneurysm/pseudoaneurysm, arteriovenous malformations, or to occlude non-bronchial collateral vessels. Although liquid embolic agents such as n-Butyl-2-cyanoacrylate (NBCA) were less preferred in the past due to fear of distal embolization causing pulmonary ischemia/infarction, more recent studies have shown similar safety and efficacy of using such liquid agents compared to PVA particles. NBCA have also been shown to achieve better hemoptysis control rates and higher long-term hemoptysis-free survival rates when compared to PVA in patients with bronchiectasis. |
| When using particles to perform bronchial artery embolization, what embolic and which particle sizes should be avoided and why? | Gelfoam is not desirable as it can lead to early recanalization and rebleeding. PVA particles and microspheres smaller than 300 um should be avoided, as these particles can pass through broncho-pulmonary anastomoses which have a mean diameter of 325 um, thus increasing the risk for pulmonary ischemia or infarct. If smaller embolic sizes are used, embolization should be performed super-selectively using 3 Fr or smaller microcatheters. |

## General Step by Step

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| What are the options for arterial access in bronchial artery angiography and embolization? | Femoral artery access is the preferred route for bronchial artery embolization due to better angulation. In cases with more complex anatomy that preclude femoral access, such as tortuosity of aorta, radial access, and even transaxillary routes have been reported. |
| What is the typical angiographic appearance of bronchial arteries contributing to hemoptysis? | Hypertrophied and tortuous. Dense networks of neovascularity and hypervascularity are often seen. |
| What should always be done after the occlusion of vascular injury to rule out continued bleeding from collateral blood supply? | After embolization, performing a post-procedural aortic angiogram is vital to ensure adequate arterial occlusion and to evaluate for any collateral branches not previously visible that require embolization. |
| How can one evaluate for successful bronchial artery embolization? | Clinical cessation of bloody sputum expectoration. |
| What is the reported short-term recurrence rate of hemoptysis at one-month post embolization? | 2–27%. |
| What is the reported long-term recurrence rate of hemoptysis at 46-month post embolization? | 10–52%. |

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| Should embolization be performed in the setting of massive hemoptysis and absence of angiographic visualization of bleeding? | Yes. Active bleeding on angiography is often not seen. |

## Complications

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| What are the common causes of recurrent hemoptysis after bronchial artery embolization? | Though not considered complications, incomplete embolization of the target vessel, failure to find and embolize all affected bronchial vessels, failure to find and embolize collateral vessels from outside of the bronchial system, collateralization after embolization, and recanalization of the embolized bronchial artery are all possible causes of continued or re-bleeding after the procedure. |
| What are the most common side effects of bronchial artery embolization? | Transient chest pain and/or dysphagia from the occlusion of intercostal or esophageal arterial branches supplied by the bronchial arteries. |
| How are these side effects managed? | These symptoms are usually self-limited and can be treated with analgesics. |
| What is the most feared complication of bronchial artery embolization? | Anterior spinal cord syndrome from spinal cord ischemia. |
| What is the reported incidence of spinal cord ischemia? | About 1%. |

## Landmark Research

Tom LM, Palevsky HI, Holsclaw DS, Trerotola SO, Dagli M, Mondschein JI, et al. Recurrent Bleeding, Survival, and Longitudinal Pulmonary Function following Bronchial Artery Embolization for Hemoptysis in a U.S. Adult Population. Journal of vascular and interventional radiology: JVIR. 2015;26(12):1806-13.e1.

- Technical success rate of bronchial artery embolization for hemoptysis is 90%; technical failures included no bronchial or extrabronchial collateral vessel causing hemoptysis identified (3%), unsuccessful catheterization due to vessel tortuosity, vasospasm, or dissection (5%), and case termination due to major complication (2%).
- Of the technically successful cases, clinical success rates at 24 hrs and 30 days were 82% and 68%, respectively; 15% of patients required two embolization procedures while 9% required three or more embolizations; recurrent bleeding and mortality were increased in patients with sarcoidosis.
- 51% of embolization cases were preceded by bronchoscopy, of which 86% localized the bleeding.

## Common Questions

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| What should be the initial management in a patient with massive hemoptysis? | Place the patient in dependent positioning of the bleeding lung. |
| Is massive hemoptysis more commonly associated with abnormalities of the bronchial arteries or pulmonary arteries? | Bronchial arteries. |

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| What is a Rasmussen's Aneurysm? Why is it important with respect to hemoptysis? | Rasmussen's aneurysm is a post-inflammatory aneurysm or pseudoaneurysm that arise from a pulmonary artery branch adjacent to or within a tuberculous cavity. Massive hemoptysis from rupture of a Rasmussen's aneurysm is a rare but potentially fatal complication of cavitary tuberculosis. |
| What does the Artery of Adamkiewicz arise from? What is the most common level for the Artery of Adamkiewicz to arise from? | The artery arises from the anterior radicular branch of the spinal branch of the posterior intercostal artery. The artery most commonly level originates on the left, at the T8-L1 levels, though has been reported to arise from either side from the T3-L4 levels. |

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# Chapter 50
# Upper Gastrointestinal Bleeding

**Kartik Kansagra, Harout Dermendjian, and Cuong H. Lam**

## Evaluating the Patient

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| What are signs and symptoms of upper GI bleeding? | Hematemesis (bright blood or coffee-ground appearing), melena (tarry black stools), and hematochezia when brisk upper GI hemorrhage (5–10% of UGIB presents with hematochezia, 11% of hematochezia is due to an UGIB). |
| What are key components to keep in mind when evaluating patients with hemodynamic instability, regardless of etiology? | Sometimes, the first sign is tachycardia when the patient is normotensive. This may be a sign of impending instability. Additional vitals to check in a more stable patient include orthostatics. Orthostatic hypotension is diagnosed with there is a fall in systolic blood pressure by at least 20 mmHg or diastolic blood pressure by at least 10 mmHg. |

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| What are key labs to order to aid in the workup and management? | CBC, chemistry panel, Creatinine, lactate, type and screen, PT, PTT, INR.<br>Look for elevated INR in a patient not on anticoagulation to suggest underlying liver disease.<br>Use chemistry panel to evaluate BUN to suggest possible underlying uremia preventing adequate platelet function. However, BUN may also be elevated secondary to the hemorrhage. |
| What is the medical management when evaluating a patient with an upper GI bleed? | Establish 2 large bore IVs (at least 18 gauge).<br>Decide if the patient is stable or unstable. If hemodynamically unstable, begin IV fluids.<br>Type and cross the patient, but if necessary, order O negative blood. When blood products are available, initiate massive transfusion protocol per the results of the PROPPR trial.<br>If there is massive hemorrhage from esophageal varices, an esophageal balloon may be necessary.<br>Begin proton pump inhibitor therapy (IV drip or BID push).<br>If there is concern for a variceal bleed, start octreotide and antibiotics (ceftriaxone 1 g IV). |

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| What are transfusion thresholds to use? | Transfuse to keep Hgb > 7 g/dL, which was demonstrated to reduce mortality in patients with acute UGIB compared to a more liberal threshold of >10 g/dL (Transfusion Strategies for Acute Upper Gastrointestinal Bleeding).<br>For patients with CAD and hemodynamic instability, transfuse to keep Hgb > 8–9 g/dL or higher.<br>Transfuse to keep platelets >50,000 per uL or with signs of bleeding.<br>Transfuse to keep INR < 1.5 (consider Kcentra for rapid reversal in patients at concern for volume intolerance, i.e., heart failure).<br>At times for unstable patients or acute large volume of hemorrhage, transfusion may be required even with Hgb level at 8 or 9. |
| What imaging modalities can be considered as part of the evaluation? | The initial step is upper endoscopy performed by gastroenterology.<br>Rarely, a tagged RBC scan can be performed to help differentiate gastric vs. duodenal bleeding if the upper endoscopy was inconclusive.<br>Occasionally, a CT angiogram (CTA) may be performed for diagnosis, but more so to help elucidate the arterial, systemic venous, and portal venous anatomy. |
| What are scoring systems utilized to risk stratify patients with GI Bleeds? | The Rockall – vomplete versus pre-endoscopy score (first 3 categories only) |

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| Age | < 60 years | 0 |
| | 60–79 years | +1 |
| | > 80 years | +2 |
| Shock | No shock | 0 |
| | Tachycardia only | +1 |
| | Hypotension | +2 |

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| Comorbidities | No major | 0 |
| | Any except renal failure, liver failure, and/or metastatic malignancy | +2 |
| | Renal failure, liver failure, and/or metastatic malignancy | +3 |
| Diagnosis | Mallory-Weiss tear | 0 |
| | No lesion identified | 0 |
| | Other diagnosis | +1 |
| | Upper GI malignancy | +2 |
| Major stigmata of recent hemorrhage | None or dark spot only | 0 |
| | Blood in upper GI tract | +2 |
| | Adherent clot | +2 |
| | Visible or spurting vessel | +2 |

Glasgow Blatchford scoring system:

- Stratifies patients for inpatient versus outpatient management
- Takes into account Hgb, BUN, hemodynamics, symptoms, as well as cardiac and hepatic history

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| What is the first-line treatment for upper GI bleeding? | Endoscopy. It allows for diagnosis and management for many of the etiologies of upper GI bleeding. |
| If GI bleeding is not controlled with endoscopy, what IR procedures exist for further management? | Non variceal – endovascular arterial embolization.<br>Esophageal variceal hemorrhage – transjugular intrahepatic portosystemic shunt (TIPS)<br>Gastric variceal hemorrhage – balloon/coil/plug-occluded/assisted retrograde transvenous obliteration (BRTO/CARTO/PARTO).<br>Keep in mind that BRTO/CARTO/PARTO may lead to esophageal varices or worsen ones that are already present. |

## High Yield History

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| What are the causes of upper GI bleeding? | Gastric and duodenal ulcers, gastritis, esophagitis, esophageal or gastric varices, angiodysplasia, Mallory-Weiss syndrome, mass/malignancy, Dieulafoy's lesion, aortoenteric fistula (consider in a patient with prior endovascular aortic aneurysm repair), and medication related. |
| How may the past medical history of a patient help guide the etiology of the bleed? | Does the patient have history of liver disease?<br>If so, do they have a prior upper endoscopy demonstrating esophageal varices? This is key as the initial management of a variceal bleed is different than non-variceal.<br>History of alcoholism?<br>This may suggest variceal hemorrhage, gastritis, or Mallory-Weiss.<br>History of chronic NSAID use or known *H. pylori* infection?<br>Gastric or duodenal ulcer.<br>History of aortic stenosis?<br>Angiodysplasia.<br>History of AAA or prior EVAR?<br>Aortoenteric fistula.<br>History of pancreatitis?<br>Splenic vein thrombosis with associated varices. |
| Why is it important to determine the patient's underlying cardiopulmonary health status? | History of coronary artery disease will help guide transfusion management. Also, severe CAD or ischemic cardiomyopathy patients may be less tolerant of acute hemoglobin drop. Low EF patients require careful volume resuscitation. If an intervention or procedure is planned, understanding the overall health is key to help reduce periprocedural complications. |

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| What neurological symptoms or key history findings should be identified? | A history of encephalopathy or active encephalopathy is important to recognize in patients with variceal bleeding as a potential treatment (TIPS) may worsen the disease process. |

## Indications/Contraindications

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| What are the indications for endovascular treatment of upper GI bleeding? | Failed endoscopic management<br>Contraindications to endoscopy secondary to medical or anatomic reasons |
| What are absolute contraindications to TIPS? | Severe or rapidly progressive liver failure<br>History of severe encephalopathy<br>Heart failure, especially right-sided heart failure<br>Pulmonary Hypertension |
| Classicaly what MELD score is considered high risk for perioperative mortality for TIPS? | MELD > 25. |
| At what MELD score is the 3-month survival rate lower after elective TIPS creation? | MELD > 17. |
| What are relative contradictions to BRTO/CARTO/PARTO? | Large esophageal varices and decompensated cirrhosis with poorly controlled ascites. |

## Relevant Anatomy

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| What anatomic landmark separates upper from lower gastrointestinal bleeding? | Ligament of Treitz. |
| What artery would you target first? | The celiac artery should be interrogated first in an attempt to evaluate the gastroduodenal artery. Additional arteries to consider are the gastric arteries and the SMA to evaluate for collateral flow to sites of bleeding in the GDA distribution. |
| What are angiographic findings for upper GI bleeding? | Contrast extravasation and contrast pooling on venous phase. |
| What can be given to help limit bowel motion (misregistration) artifact for angiograms? | IV Glucagon. |

## Relevant Materials

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| What type of embolic agents should be readily available? | Polyvinyl alcohol particles (PVA), coils, Onyx, gelfoam, vascular plugs, and n-Butyl-2-cyanoacrylate (NBCA; glue). |
| For TIPS, what additional equipment may be helpful? | Access to transabdominal or different types of intravascular ultrasound may aid in direct visualization of the TIPS needle and help reduce the number of needle passes. |

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| For BRTO/CARTO/ PARTO what equipment may be helpful? | A long sheath may be helpful to maintain access within the shunt. Also, a variety of microcatheter systems may help to navigate the tortuosity often encountered within the varices. |
| What is the unique feature of the Gore Viatorr TIPS Endoprosthesis? | It has "controlled expansion" technology, meaning it is usually first dilated to 8 mm, though it can be ballooned to a larger diameter in subsequent procedures if clinically required based on continued symptoms following the initial TIPS. |
| What are some of the various sclerosant agents available when performing a retrograde transvenous obliteration? | STS, Polidocanol, n-Butyl-2-cyanoacrylate (NBCA), and ethanol. |

## General Step by Step

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| What are the access options for the various interventions? | Arterial embolization: Femoral, brachial, and radial.<br>TIPS: Right internal jugular vein is preferred. May need femoral vein access if using simultaneous intravascular US for guidance.<br>BRTO: Femoral vein or right internal jugular veins. If a TIPS is present, consider antegrade approach and use a transjugular approach. Also, possible transhepatic or trans-splenic access may be considered if there are anatomic limitations to the more conventional approaches. |

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| Once you have access, what are the steps for embolization? | Using preferred catheter and microcatheter perform multiple digital subtraction angiograms to identify the correct area of bleeding. Once confirmed, perform embolization to stasis. Perform a post embolization angiogram. As mentioned, consider an SMA angiogram to look for collateral flow to the site of extravasation. |
| If utilizing coils for embolization of the GDA, what is the general technique for where to place the coils and why? | Ideally, subselective branch embolization should be performed, though in cases where the GDA is to be sacrificed, proximal and distal control of the vessel should be obtained to prevent retrograde bleeding. |
| How is a TIPS shunt placed? | Once systemic venous access is obtained, pressures are measured and the pre-TIPS portosystemic gradient is calculated. Using a 10-Fr sheath and a curved MPA catheter, the hepatic vein (usually right hepatic) is selected. The catheter is exchanged for the TIPS needle and used to access the portal vein.<br>Then, through access is obtained with an 0.035″ wire and a 5F sheath is advanced into the portal vein, preferably one with side holes and radiopaque markers to help determine the length of the stent. The liver parenchymal tract is then pre-dilated for passage of the stent. The access sheath is then advanced into the portal vein and the stent is advanced into position. The sheath is drawn back and the stent is deployed. A final portogram is performed to confirm appropriate positioning. Post-TIPS portosystemic gradient is again calculated. |

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| How is a BRTO/CARTO/PARTO performed? | Access is obtained usually via a femoral approach. Then, using various wires, support catheters, and sheaths, the goal is to obtain access into the splenorenal shunt. If performing a BRTO, a balloon occlusion catheter is used to occlude the shunt and retrograde venogram is performed. Once the varices have been mapped, any preferred sclerosant agent is used. Usually, a point of completion is just prior to overspill of sclerosant into the portal venous system. When doing a CARTO or PARTO, the prolonged balloon occlusion is substituted for coils and plugs, respectively. |

## Complications

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| Why is ischemia less common in upper GI embolization? | There is a rich network of collaterals feeding the stomach and duodenum. If the patient has had prior embolization of surgery, the risk for ischemia is higher. |
| What are potential sequela of retrograde transvenous obliteration? | Worsening ascites and esophageal varices. |
| What are common complications of embolization therapy? | Non-target embolization, which may result in bowel infarction, as well as access site complications (hematoma and pseudoaneurysm). |
| What are potential complications of TIPS? | Hepatic encephalopathy, intra-abdominal bleeding, CHF, and acute liver failure/decompensation. |

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| How do you treat post-TIPS encephalopathy? | Patients can be started on lactulose 30 g, three times a day and titrated to 3 loose bowel movements a day. Also, consider an induction dose of up to 120 g a day. Additionally, patients can be placed on Rifaxamin 550 mg, 2 times a day. If medical therapy is not enough, the TIPS diameter can be reduced and, if required, the TIPS can be occluded. |

## Landmark Research

García-Pagán JC, Caca K, Bureau C, Laleman W, Appenrodt B, Luca A, et al. Early Use of TIPS in Patients with Cirrhosis and Variceal Bleeding for the Early TIPS (Transjugular Intrahepatic Portosystemic Shunt) Cooperative Study Group. N Engl J Med [Internet]. 2010;362(10):2370–9.

The target population of the Early TIPS Cooperative Study included 63 patients with cirrhosis and acute variceal bleeding who had been treated with vasoactive drugs plus endoscopic therapy randomized to PTFE covered stent within 72 hours after randomization or continuation of vasoactive-drug therapy.

- Patients with acute variceal bleeding and high risk for treatment failure, early use of TIPS was associated with significant reduction in treatment failure and mortality.
- Rebleeding or failure to control bleeding occurred in 14 out of 31 patients randomized to drugs and endoscopic band ligation and in 1 out of 32 patients randomized to TIPS.

Jairath V, et al. Restrictive Versus Liberal Blood Transfusion for Acute Upper Gastrointestinal Bleeding (TRIGGER): A Pragmatic, Open-Label, Cluster Randomised Feasibility Trial. Lancet. 2015. 386(9989):137–44.

- Multicenter clustered RCT randomized patients to a restrictive (Hgb < 8 g/dL) or liberal (Hgb <10 g/dL)

transfusion policy. 936 patients – 403 to restrictive and 533 to a liberal policy
- Non-significant reduction in RBC transfusion in the restrictive policy
- No significant difference in clinical outcomes

Villanueva C et al. Transfusion strategies for acute upper gastrointestinal bleeding. The New England Journal of Medicine. 2013. 368(1):11–21.

- Probability of survival at 6 weeks was higher in the restrictive strategy group (transfusion for Hgb <7 g/dL) (95% vs 91%).
- Further bleeding occurred in 10% of restrictive strategy patients compared with 16% of patients in the liberal-strategy group.
- Survival was significantly higher in patients with cirrhosis and Child-Pugh class A or B.

## Common Questions

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| What are the causes of upper GI bleeding? | Gastric and duodenal ulcers, gastritis, esophagitis, esophageal or gastric varices, angiodysplasia, Mallory-Weiss syndrome, mass/malignancy, Dieulafoy's lesion, aortoenteric fistula, and medication related. |
| What are factors predictive of endoscopic failure? | Patients presenting with shock, large ulcer and located along posterior duodenum, and Hgb < 10. |
| What is commonly used to risk stratify perioperative risk in patients undergoing TIPS and what are its components? | MELD. It is made up of Cr, total bilirubin, and INR. MELD-Na score corrects for serum sodium. |

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| What is the mechanism of action of lactulose in treating hepatic encephalopathy? | Lactulose is metabolized by colonic bacteria to create an acidic environment and reduce the breakdown of nitrogen-containing products to ammonia and other cerebral toxins. |
| What is the anatomic landmark that separates upper from lower GI bleeding? | Ligament of Treitz. |

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# Chapter 51
# Lower Gastrointestinal Bleeding

**Christopher Barnett**

## Evaluating the Patient

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| Describe the relationship of bleeding severity with hemodynamic stability. | Worsening hypovolemia correlates with worsened hemodynamic instability, manifesting in degrees of tachycardia, hypotension, and altered mental status, in addition to other signs of shock such as dyspnea and decreased urine output. |
| Describe some important initial management considerations for a patient presenting with hematochezia. | Obtain vital signs, establish large-bore IV access for resuscitation with crystalloid and blood products as necessary, provide supplemental oxygen, and correct any underlying coagulopathy, if possible. |
| What basic labs should be assessed? | Complete blood count, complete metabolic panel, coagulation studies, type and screen or cross-match. |

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| When evaluating for possible LGIB, what other source of bleeding should also be considered? | An upper GI bleed, which if brisk, may cause hematochezia. An upper GI bleed may be excluded with nasogastric lavage or upper endoscopy as clinically indicated. |
| What are the primary imaging modalities for diagnosing LGIB? | Computed tomography angiography (CTA), nuclear red blood cell (RBC) scintigraphy, and direct catheter angiography. |
| What are the minimum flow rates required to detect bleeding by these different imaging modalities? | RBC scintigraphy: $\geq$ 0.1 mL/min<br>CTA: > 0.35 mL/min<br>Catheter angiography: $\geq$ 0.5 mL/min |
| Compare CTA and RBC scintigraphy for the diagnosis of LGIB. | Generally, CTA should be obtained first, as it is faster, more accurately localizes bleeding, and may identify underlying pathology contributing to bleeding. Bleeding visualized on CTA is also more likely to correlate with a positive arteriogram. RBC scintigraphy is more sensitive but offers less precise bleed localization and may be less readily available. RBC scintigraphy may be helpful following a negative CTA in the setting of intermittent bleeding, as it involves continuous imaging over a 1–2 hour duration. |
| RBC Scintigraphy utilizes what radiotracer? | Technetium-99m. |
| What phases are typically included in a CTA for diagnosis of GI bleeding? | Non-contrast, late arterial, and delayed venous phases. |

## High Yield History

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| Patients with acute LGIB typically present with what main symptom? | Hematochezia; however bleeding from the right-sided colon or small bowel may present as melena. |
| What is the most common cause of lower GI bleeding in adults? | Diverticular disease (~30%). |
| What are some additional common causes? | Angiodysplasia, inflammatory bowel disease, ischemia, neoplasm, infectious colitis, rectal ulcer, radiation colitis/proctitis, hemorrhoids, and post-polypectomy bleeding. |

## Indications/Contraindications

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| What has traditionally been the first-line intervention for hemodynamically stable patients with lower GI bleeding? | Often colonoscopy, which may potentially localize the source of bleeding and has potential to sample specimens, as well as provide therapeutic management. |
| In what scenarios might colonoscopy be limited or not an ideal first-line intervention? | Colonoscopy is limited in emergent settings in which patients often cannot tolerate nor wait for bowel preparation, and in whom significant active hemorrhage may obscure direct visualization of a bleeding source. Additionally, endoscopy provides a limited assessment of small bowel. Thus, CTA is increasingly becoming a first-line evaluation for LGIB in some centers. |

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| What are the indications for catheter angiography? | Bleeding refractory to medical or endoscopic treatment, non-diagnostic endoscopy, or patients too unstable for endoscopy. Given the potential limitations of endoscopic intervention, some institutions prefer angiographic embolization as the primary therapy for LGIB. |
| What are contraindications to catheter angiography and/or embolization for LGIB? | Generally, contraindications to angiography are relative and relate to potential harms of contrast administration (e.g., severe allergic reaction or renal disease), or uncorrectable coagulopathy, in which case the risks and benefits of intervention must be considered. Potential contraindications to embolization itself include inability to identify bleeding or to super-select the bleeding artery, concurrent bowel ischemia, or surgically altered vascular anatomy, which may increase the resulting ischemia and lead to unwanted infarction. |
| Describe scenarios in which surgery may be preferable to embolization. | For example, if bleeding is not focal such as in the setting of inflammatory bowel disease, then it may not be amenable to target embolization. Additionally, if the source of bleeding were to itself ultimately require resection, such as a bowel malignancy, then it may be reasonable to manage directly with surgery. |

## Relevant Anatomy

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| How is lower gastrointestinal bleeding (LGIB) defined anatomically? | Gastrointestinal bleeding originating distal to the ligament of Treitz. |
| The arteries supplying the ileum and jejunum branch from what major artery? | The superior mesenteric artery (SMA). |
| Name the main arterial branches from the SMA suppling the colon. | The ileocolic, right colic, and middle colic arteries. |
| Name the major branches of the inferior mesenteric artery (IMA). | Left colic artery, sigmoid arteries, and superior rectal artery. |
| From where does the middle rectal artery branch? | The internal iliac artery anterior division, It anastomoses with distal superior rectal branches of the inferior mesenteric artery. |
| The inferior rectal artery branches from what artery? | The internal pudendal artery, a branch of the internal iliac artery anterior division. |
| Discuss the significance of collateral circulation in management of LGIB. | The gastrointestinal tract's rich collateral blood supply allows for super-selective embolization to achieve hemostasis without completely de-vascularizing the involved bowel, thereby mitigating the risk of bowel infarction. Thus, it is important to recognize that bowel that is surgically altered or has undergone radiation therapy may have diminished collateralization and be more prone to infarction. |

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| What anastomoses provide the major collateral circulation between the SMA and IMA? | The arc of Riolan and marginal artery of Drummond. |

## General Step by Step

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| What is the typical catheter angiography access for LGIB? | Transfemoral |
| What sheath size is generally necessary? | 5-French (Fr) sheath to allow for visceral vessel catheterization, with coaxial microcatheter advancement for super-selection of the bleeding vessel. |
| Which vessels should be interrogated, and in what order? | Vessels may be selected in the order of suspected bleeding source. For instance, if small bowel or right-sided colonic bleeding is suspected then the SMA may be interrogated first, whereas if bleeding is suspected from the descending colon, then the IMA may be selected first. Of note, as procedural contrast fills the bladder, the IMA circulation may be gradually obscured. |
| Which medication can be given to reduce bowel motion (misregistration) artifact during catheter angiography? | Glucagon (1 mg Intravenously). |

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| Discuss complications/ contraindication to glucagon administration. | Side effects are typically mild, most frequently including nausea/vomiting Glucagon administration should be avoided in patients with known hypersensitivity, pheochromocytoma, insulinoma, or glucagonoma. |
| In the event of negative angiography due to intermittent bleeding, what is sometimes performed to facilitate the localization of hemorrhage? | Provocative angiography, in which vasodilators, anticoagulants, or thrombolytics are injected to induce bleeding after an initially negative mesenteric angiogram.<br>A technique described by Kim et al. is to initially administer an intraarterial vasodilator and heparin within an artery of suspicion and subsequently repeat angiography, which if negative is followed by immediate infusion of tissue plasminogen activator (tPA) in incremental doses with repeat angiography performed until a source if bleeding is identified, or until a maximum dose of tPA has been given based on operator discretion and patient characteristics. |
| Once bleeding is identified, what agents are available for treatment? | Many options are available, including endovascular coils, microparticles, such as gelatin sponge and polyvinyl alcohol (PVA), and liquid embolics, such as n-Butyl-2-cyanoacrylate (NBCA) glue. |

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| Discuss some major considerations in selecting an embolic agent. | Choice of embolic agent is primarily based on operator preference. Endovascular coils are commonly used, with the advantage of being deployed precisely and with relative preservation of the distal vasculature. The main limitations of coils are that they permanently occlude the targeted vessel and they rely on a patient's intrinsic ability to form a thrombus at the site of coil placement. Glue (n-Butyl-2-cyanoacrylate; NBCA) and creation of a glue cast may be desirable and effective in the settings of coagulopathy but requires a high level of operator familiarity and has increased potential for non-target embolization, as well as ability to polymerize within the catheter and at the catheter tip, which may adhere to the vessel wall and impede removal of the catheter. Compared to coils, particulate and liquid embolics have potential to occlude distal vasculature at the arteriole level, which may carry a higher risk of bowel infarction. |
| At what arterial level should target embolization be performed? | Embolization should be performed as distal to the site of bleeding as possible within the marginal arteries or vasa recta. An animal study demonstrated that ischemic bowel injury risk can be reduced by limiting the number of embolized vasa recta to three. |
| Following embolization, what additional steps should be performed? | Angiography to confirm cessation of bleeding. If additional bleeding from collateral a vessel is visualized, then the collateral vessel should be embolized, if possible. |

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| What should be included in the post-procedural assessment? | Serial examination of puncture site and peripheral pulses, monitoring of vital signs, urine output, hemoglobin and hematocrit, transfusion requirement, and renal function. Additional signs of ongoing bleeding should be assessed for, such as hematochezia or melena. |

## Complications

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| What is the rate of significant ischemia following the embolization for LGIB? | Approximately 5%. |
| What is the estimated post-embolization re-bleeding rate? | 22–56%. |
| In the event of re-bleeding, what interventions should be considered? | Endoscopy, repeat angiography, or surgery. |

## Landmark Research

"Arteriography for Lower Gastrointestinal Hemorrhage: Role of Preceding Abdominal Computed Tomographic Angiogram in Diagnosis and Localization."

Jacovides CL, Nadolski G, Allen SR, Martin ND, Holena DN, Reilly PM, et al. Arteriography for Lower Gastrointestinal Hemorrhage: Role of Preceding Abdominal Computed Tomographic Angiogram in Diagnosis and Localization. JAMA Surg. 2015 Jul;150(7):650–6.

- Prospective study to help guide the use of diagnostic imaging prior to catheter angiography in the setting of acute LGIB.
- Compared to RBC scintigraphy, CTA resulted in better localization of bleeding and corresponded to a greater number of positive catheter angiography evaluations.

"Superselective Arterial Embolization for the Treatment of Lower Gastrointestinal Hemorrhage"

Bandi R, Shetty PC, Sharma RP, Burke TH, Burke MW, Kastan D. Superselective arterial embolization for the treatment of lower gastrointestinal hemorrhage. J Vasc Interv Radiol. 2001 Dec;12(12):1399–405.

- Retrospective review over a 12-year period to determine the safety and efficacy of transcatheter embolization for LGIB.
- Concluded that embolotherapy was not only successful at controlling LGIB, but did not result in significant bowel ischemia or infarction on follow-up patient evaluations.

"Provocative Mesenteric Angiography for Lower Gastrointestinal Hemorrhage: Results from a Single-institution Study"

Kim CY, Suhocki PV, Miller MJ, Khan M, Janus G, Smith TP. Provocative mesenteric angiography for lower gastrointestinal hemorrhage: results from a single-institution study. J Vasc Interv Radiol. 2010 Apr;21(4):477–83.

- Retrospective study demonstrating that in patients with recurrent occult lower GI bleeds, provocative mesenteric angiography with injection of a vasodilator and tissue plasminogen activator resulted in successful identification and treatment of the bleed in one third of patients.
- No bleeding complications related to administration of thrombolytic therapy were identified.

## Common Questions

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| What is the incidence of LGIB? | 20–27 cases per 100,000 persons. |
| Lower GI bleeds make up what percentage of overall GI bleeds? | Approximately 20–24%. |
| In what percentage of LGIB will bleeding stop spontaneously? | 80–85%. |

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| What is the first clinical sign of mild-moderate hypovolemia in a stable patient? | Resting tachycardia. |
| Approximately what percentage of blood loss begins to result in decreased systolic blood pressure? | 15–30%. |
| Which types of lesions have a particularly increased risk of bleeding recurrence following embolization? | Angiodysplasias and arteriovenous malformations (AVM). |

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# Chapter 52
# Uterine Artery Embolization – Vascular Emergency

**Kartik Kansagra and Cuong H. Lam**

## Evaluating the Patient

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|---|---|
| What is the first step when evaluating the patient? | Assess for hemodynamic stability using vital signs. Look for low blood pressure with tachycardia, orthostatic hypotension |
| What are key labs to order to aid in the work up and management? | Chemistry panel, CBC, Cr, lactate, type and screen, PT, PTT, INR. |
| What is the transfusion approach to consider when patient is unstable? | Establish 2 large bore IVs and begin IV fluids<br>Once available initiate mass transfusion protocol per the results of the PROPPR trial |

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| In the setting of trauma what else should be considered? | Pelvic banding or wrapping should be initiated immediately |
| What are transfusion thresholds to use? | Tranfuse to keep Hgb > 7 g/dL. For patients with CAD and hemodynamic instability transfuse to keep Hgb > 8–9 g/dL<br>Transfuse to keep platelets > 50000 per uL or with signs of bleeding<br>Tranfuse to keep INR < 1.5<br>At times for unstable patients or acute large volume of hemorrhage transfusion may be required even with hgb level at 8 or 9 |
| What imaging modalities can be considered as part of the evaluation? | CT Angiogram may show extravasation but also will help elucidate the arterial anatomy. May also aid with diagnosing the etiology |
| What differentiates primary from secondary PPH? | Primary: blood loss > 500 cc within 24 hours of delivery<br>Secondary: Excessive vaginal bleeding occurring from within 24 hours and lasting up to 6 weeks after delivery |
| What are emergent or medical options to consider when treating significant postpartum bleeding? | Uterotonics (oxytocin), manual massage, prostaglandins, coagulopathy correction, balloon tamponade of uterus, surgical exploration/repair, compression sutures |

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| At what timepoints may endovascular therapies be utilized? | Emergent UAE<br>Bilateral hypogastric artery balloon placement for insufflation during delivery or surgery<br>UAE prior to surgery<br>UAE after delivery and prior to medical management or surgery (uterine-preserving cesarean)<br>As opposed to extirpative surgical management (cesarean hysterectomy; complicated by possible catastrophic bleeding), conservative c-section with the placenta left in-situ allows for the possibility of placental involution and medical management with methotrexate, though is prone to complications of sepsis and delayed hemorrhage |
| What are the surgical options? | Emergent hysterectomy, uterine artery ligation |

## High Yield History

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| What are causes of significant uterine bleeding? | Postpartum hemorrhage, tumor-related bleeding, abnormal placentation, ectopic pregnancy related hemorrhage, massive abnormal uterine bleeding related to fibroids, malformation (acquired or congenital), and trauma |
| What is considered significant postpartum hemorrhage? | Bleeding that is > 500 cc in vaginal delivery and > 1000 cc in cesarean delivery |
| What is the leading cause of death in patients younger than 44? | Trauma. The major risk factor for poor outcomes are related to hemorrhagic shock |
| What proportion of patients with MAP require blood transfusion? | MAP is a life-threatening condition with a maternal mortality rate near 7%. 90%. 40% require more than 10 units |

## Indications/Contraindications

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| What are indications for emergent uterine artery embolization? | Preoperative prior to delivery in the setting of abnormal placentation<br>Trauma with persistent or recurrent hemodynamic shock, ongoing hemorrhage, CT evidence of contrast extravasation, large or expanding retroperitoneal hematoma identified on laparotomy, penetrating trauma<br>Bleeding from any of the above-mentioned etiologies that is clinically significant |
| What are contraindications to the procedure? | Absolute: In the setting of trauma hemoperitoneum requires surgical exploration<br>Relative: Pregnancy |

## Relevant Anatomy

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| Where does the uterine artery traditionally originate? | It is a branch off the anterior division of the internal iliac artery |
| What anatomic arterial variants must you be cognizant of? | Uterine-ovarian anastomoses. These are even more clinically relevant when utilizing permanent embolic agents |

## Relevant Materials

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| What type of embolic agents should be readily available? | Polyvinyl alcohol particles (PVA), embolic microspheres, coils, Onyx, gelfoam, vascular plugs, N-butyl 2-cyanoacrylate glue |

| | |
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| What size particles are often used for uterine artery embolization? | 300–500 um or 500–700 um diameter particles. Smaller particles have the advantage of more distal occlusion thus reducing the chance of collateral flow |

## General Step by Step

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| What access options are available? | The traditional access site was the femoral artery; however, with newer tools radial is a reasonable alternative. Also available is brachial access |
| What are the general steps for emergent uterine artery embolization? | First a pelvic angiogram is usually performed with a flush catheter to identify the origin of the uterine artery. Then a 4 or 5 French catheter is guided into the internal iliac artery. A microcatheter system is advanced coaxially through the 4 or 5 French catheter to perform selective angiography of the uterine artery. The entire vaginal canal should be visualized and any intrauterine balloons should be deflated during angiography. The microcatheter is then utilized to administer the embolic agent of choice |
| What is the purpose of the post- embolization aortogram? | It helps to identify any collateral feeders from the ovarian and inferior epigastric arteries |
| What is the angiographic endpoint of treatment? | Persistent column of contrast beyond 5 heart beats |

## Complications

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| What are common complications of embolization therapy? | Pain, non-target embolization resulting in possible buttock ischemia, small bowel necrosis, ovarian infarction, vaginal or cervical necrosis, or bladder necrosis, access site complications (hematoma and pseudoaneurysm), vaginal discharge (ensure not purulent) |
| What is post-embolization syndrome? | Expected post-procedure syndrome manifesting with abdominal pain, fever, nausea, leukocytosis, and vomiting |
| Are there any possible neurological complications? | Case series have reported temporary neuropathy of the sciatic nerve, perineal paralysis, and lower limb numbness and paresthesias. However, the most common long-term neurologic complication is mild buttock numbness |

## Landmark Research

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- 680 patients with severe trauma injury receiving massive transfusion randomized to a 1:1:1 ratio of plasma:platelets:RBC to a 1:1:2 ratio.
- There was no difference in mortality at 24 hours or 30 days between a 1:1:1 and 1:1:2 protocol.
- 1:1:1 group had greater proportion of hemostasis and lower mortality due to exsanguination at 24 hours.

Sentilhes L, et al. Predictors of Failed Pelvic Arterial Embolization for Severe Postpartum Hemorrhage. Obstetrics and Gynecology. 2009; 113: 992–999.

- 100 patients over 13 years.
- Clinical success in 89% of patients.
- Patients who failed embolization had a higher rate of estimated blood loss and higher transfusion requirements, which may indicate delay in seeking endovascular options for management.

Doumouchtsis, S, et al. Menstrual and Fertility Outcomes Following the Surgical Management of Postpartum Haemorrhage: A Systematic Review. British Journal of Oncology. 2014; 121: 382–388.

- 28 studies included.
- Approximately 92% of patients resumed menstruation.
- 75% of patients achieved conception following embolization.
- Number and quality of available evidence is of concern.

Lee, et al. Outcomes of Balloon Occlusion in the University of California Morbidly Adherent Placenta Registry. American Journal of Obstetrics and Gynecology MFM. 2020 Feb; 2(1): 1–10.

- 5 centers, 171 patients.
- Aortic and iliac artery balloon occlusion are associated with decreased EBL, transfusions, ICU admissions, and adverse events compared to internal iliac artery ligation or no adjunctive interventions.

Wang, et al. Uterine Artery Embolization following Cesarian Delivery but prior to Hysterectomy in the Management of Patients with Invasive Placenta. JVIR. 2019; 30: 687–691

- UAE following cesarian delivery but before hysterectomy in patients with placenta increta appears to be safe and effective in decreasing EBL, transfusion requirements, and length of ICU stay compared with cesarean-hysterectomy alone.

## Common Questions

| | |
|---|---|
| What are causes of significant uterine bleeding? | Postpartum hemorrhage, tumor related bleeding, abnormal placentation, ectopic pregnancy related hemorrhage, massive abnormal uterine bleeding related to fibroids, and trauma |
| Why is the incidence of MAP increasing? | Increasing performance of uterine instrumentation |
| What branch of Internal iliac does the uterine traditionally come off of? | The anterior division |
| What is the benefit of gel foam embolization? | It is a temporary embolic agent |

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# Chapter 53
# Contrast Reactions

**Matthew Czar Taon**

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| Describe the prednisone-based and methylprednisolone-based oral premedication regimens for allergic and allergic-like contrast reactions | The prednisone-based regimen involves administering 50 mg prednisone by mouth at 13 hours, 7 hours, and 1 hour before contrast medium administration, plus 50 mg diphenhydramine intravenously, intramuscularly, or by mouth 1 hour before contrast medium administration.<br>The methylprednisolone-based regimen involves administering 32 mg methylprednisolone by mouth 12 hours and 2 hours before contrast medium administration with an option to include 50 mg diphenhydramine. |

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| What are the classifications of acute adverse events related to contrast administration? | Acute adverse events can be categorized into allergic-like or physiologic adverse events. They can be further organized by severity into mild, moderate, or severe events. Distinguishing allergic-like reactions from physiologic reactions is important because allergic-like reactions may require future premedication with steroids whereas physiologic reactions do not require premedication. |
| In what situations should accelerated intravenous contrast-allergy premedication be considered? | A patient who can take nothing by mouth (NPO). An outpatient with a prior allergic-like or unknown reaction to the same class of contrast medium who has not received premedication and whose exam or procedure cannot be easily rescheduled.<br>An emergency department patient or inpatient with a prior allergic-like or unknown reaction to the same class of contrast medium in whom the use of 12- or 13-hour premedication will adversely delay care. |
| What clinical signs or symptoms associated with severe contrast extravasation warrant a surgical consultation? | Progressive swelling or pain, altered tissue perfusion, decreased capillary refill at any time after contrast extravasation, development of focal paresthesia, change in sensation in the affected limb, worsening passive or active range of motion, or skin ulceration or blistering. |

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| Which patients are at highest risk of developing nephrogenic systemic fibrosis? | Patients undergoing dialysis and those with stage 4 (glomerular filtration rate, 30–40 mL/min per 1.73 $m^2$) or stage 5 (glomerular filtration rate < 30 mL/min per 1.73 $m^2$) chronic kidney disease. |
| If a post-contrast patient develops hives or diffuse erythema with associated hypotension or respiratory distress, what steps must be taken? | Administer the following:<br>Oxygen at a rate of 6–10 L/min via face mask<br>0.9% Normal saline (NS) wide open<br>Epinephrine 0.3 cc of 1:1000 IM (or autoinjector) or Epinephrine 1 cc of 1:10,000 IV with slow flush or IV fluids<br>Elevate the legs > 60° and considering calling 911 or CODE BLUE based on severity. |
| If a post-contrast patient develops hypotension with tachycardia (anaphylactoid reaction), what steps must be taken? | Preserve IV access, monitor vitals q 15 m, and elevate the legs > 60 degrees. Administer the following:<br>Oxygen 6–10 L/min via face mask<br>0.9% NS wide open<br>Epinephrine 0.3 cc of 1:1000 IM (or autoinjector) or Epinephrine 1 cc of 1:10,000 IV with slow flush or IV fluids<br>Considering calling 911 or CODE BLUE based on severity. |
| What are the hallmarks of a vasovagal reaction? | Hypotension with bradycardia (heart rate < 60). |

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| If a post-contrast patient develops expiratory wheezing and hypoxia, suggestive of bronchospasm, what steps must be taken? | Preserve IV access and monitor vitals.<br>Administer the following:<br>Oxygen 6–10 L/min via face mask.<br>Beta-2 agonist inhaler (Albuterol 90 mcg/puff) 2 puffs; repeat x 3.<br>If not responding or severe, then use Epinephrine 0.3 cc of 1:1000 IM (or autoinjector) OR Epi 1 cc of 1:10,000 IV with slow flush or IV fluids 5.<br>Consider calling 911 or CODE BLUE based on severity. |
| If a post-contrast patient develops stridor or hypoxia, suggestive of laryngeal edema, what steps must be taken? | Preserve IV access and monitor vitals. Administer oxygen 6–10 L/min via face mask and Epinephrine 0.3 mL of 1:1000 IM (or autoinjector) or Epinephrine 1 mL of 1:10,000 IV with slow flush or IV fluids. Considering calling 911 or CODE BLUE based on severity. |

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# Part IX
# Lymphatic

# Chapter 54
# Thoracic Duct Embolization

**Kyle A. Wilson and Bill S. Majdalany**

## Evaluating the Patient

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| What objective criteria are used to diagnose a true chylous effusion? | Fluid triglycerides should be > 110 mg/dL and the cholesterol should be less than the serum cholesterol.<br>The specific gravity of the fluid should be > 1.012.<br>Effusion should contain chylomicrons.<br>Cell differential is often > 70% lymphocytes.<br>Patients on a low-fat diet or total parenteral nutrition (TPN) may not meet these criteria, but may still have a chylous effusion |
| What labs should be obtained prior to TDE? | Fluid analysis of the effusion to confirm the diagnosis of chylothorax, coagulation profile (PT/INR and PTT), complete blood count |

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| What are the most common patient symptoms and presentations of a chylous pleural effusion? | Most commonly, pleural effusions present with dyspnea, chest pain, fever, and fatigue are all common symptoms. Frequently, unilateral or bilateral chest tubes will be in place post-operatively. |
| What imaging should be reviewed prior to TDE or TDD? | A chest X-ray can screen for pleural effusions and exclude alternative causes of dyspnea.<br>Reviewing cross-sectional abdominal imaging is helpful to exclude anatomic abnormalities (abdominal aortic aneurysm (AAA), horseshoe kidney, etc.) and plan a safe access.<br>Lymphangiography is usually adequate to diagnose traumatic chylous effusions.<br>In the setting of non-traumatic chylous effusion, magnetic resonance (MR) lymphangiography may be helpful to detect masses, collaterals, leaks, or retrograde lymphatic flow prior to the procedure. |
| What position does the patient need to maintain? | The patient will be supine. It is helpful to assess the patient's pulmonary reserve in the supine position. If dorsal pedal lymphangiography will be performed, their feet should hang off the end of the table at the ankles for greater patient comfort. |

## High Yield History

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| Define a traumatic chylous effusion, and give examples of traumatic etiologies. | Traumatic chylous effusions are attributable to recent trauma, often as a complication of cardiothoracic or neck surgeries.<br>Examples include esophagectomy, thyroidectomy, and pulmonary resections.<br>TDE and TDD have higher clinical success rates for traumatic compared to non-traumatic chylous effusions. |
| Define a non-traumatic chylous effusion, and give examples of non-traumatic etiologies. | Non-traumatic chylous effusions are not associated with recent trauma, surgery, or instrumentation.<br>They may be caused by malignancy (e.g., lymphoma, mesothelioma, lung cancer, and multiple myeloma), lymphatic vessel disease (e.g., Gorham disease, lymphangiomyomatosis, Kaposiform lymphangiomatosis) congenital disorders, systemic diseases (e.g., SLE, Behçet disease), infection (e.g., TB), disorders of lymphatic conduction (e.g., heart failure or liver cirrhosis), and idiopathic disease.<br>Lymph leaks can result from vessel malformation or masses.<br>TDE and TDD have lower clinical success rates in this patient population when compared to patients with traumatic chylous effusions. |
| What conservative therapies can be used to manage chylous effusion? | Patients can be placed on a medium-chain fatty acid diet or made *nil* per os and placed on TPN.<br>Octreotide may also be administered.<br>If conservative therapy is successful (reported rates vary from 16–80%), the effusion should resolve in two to three weeks. |

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| What surgical therapies can be used to manage a chylous effusion? | Thoracic duct ligation and pleurodesis are performed to treat chylous effusion.<br>When performed as an open surgery, this procedure has a 2.1% mortality rate and a 38.8% morbidity rate.<br>Serial thoracentesis or placement of a drain can palliate chylothorax. |
| What are the complications of chylous effusion? | Major loss of chyle can result in weakness, dehydration, nutritional deficits and metabolic disturbances, cachexia, edema, immunosuppression and hemodynamic distress as the result of hypoproteinemia, hyponatremia, and lymphopenia.<br>Mortality may be as high as 50%. |

## Indications/Contraindications

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| What threshold of daily chyle output is typically required before procedural interventions are considered? | Typically, daily chylous output < 500 mL/day can be managed conservatively, and so procedural interventions are considered once the daily output is > 500 mL/day.<br>If the output does not decrease with conservative measures or persists for greater than two weeks, more aggressive therapy may be warranted. |
| What are the absolute contraindications to TDE/TDD? | Uncontrollable coagulopathy and AAA or any other pathology that would preclude percutaneous abdominal access are the only absolute contraindications to percutaneous, transabdominal TDE/TDD.<br>Note that, in patients with AAA, the thoracic duct may be accessed and embolized in a retrograde fashion via the subclavian vein. |

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| What are the relative contraindications to TDE? | Allergy to any of the necessary materials is a contraindication to the procedure.<br>Right-to left cardiac shunts and severe pulmonary disease, especially pulmonary hypertension, can increase the likelihood that pulmonary artery embolization will be symptomatic.<br>A history of thoracic radiation can increase the possibility left-to-right shunt and cerebral embolization. |
| What are the relative contraindications to TDD? | Although cases of accidental aortic puncture have been reported without significant harm to the patient, TDD has historically not been attempted on ducts that are too near the aorta due to the risk of repeated aortic puncture and maceration.<br>TDD should only be attempted when a clear target is visualized. Therefore, poorly opacified ducts are a relative contraindication to the procedure. |

## Relevant Anatomy

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| What are the three distinct divisions of the lymphatic system and which produce the majority of the lymph in the human body? | The lymphatic system can be divided into the soft tissue or peripheral lymphatics, the intestinal lymphatics, and the liver lymphatics. The intestinal and liver lymphatics produce approximately 80% of the lymph. The intestinal system absorbs dietary fats and the liver system transports hepatic-derived proteins to systemic circulation. |

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| What is the function of the lymphatic system? | The lymphatic system collects excess interstitial protein and fluid and returns it to the venous system. It is necessary to preserve tissue oncotic and hydrostatic pressure and fluid homeostasis. |
| Describe the embryonic development of the lymphatic system. | The lymphatic primordia originate as small sacs from the veins of the jugular-axillary region, retroperitoneum, mediastinum, and pelvis. The sacs ultimately fuse, and their venous connections are obliterated, except at the junctions of the internal jugular and subclavian veins. |
| What is chyle? | Chyle is an odorless, alkaline, sterile, milky appearing fluid produced primarily by the intestines. It contains proteins, lipids, electrolytes, and lymphocytes. |
| Describe the position of the cisterna chyli. | The cisterna chyli is a polymorphous sac, 2–16 mm in diameter, that arises from the left lumbar, intestinal, and occasionally right lumbar lymphatic trunks.<br>It is usually found at L1-L2, between the aorta and the IVC.<br>All three divisions of the lymphatic system ultimately converge on the cisterna chyli. |
| Describe the position of the thoracic duct. | The thoracic duct is a 2–6 mm wide structure that arises from the cisterna chyli below the diaphragm and extends as long as 45 cm in a cephalad direction before emptying into the junction of the left internal jugular and subclavian veins. It courses from retroperitoneum to mediastinum through the aortic hiatus, and lies between the aorta and azygous vein. It usually crosses from the right of midline to the left at T5.<br>The thoracic duct is known to have multiple, parallel channels in 40–60% of cases. |

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| What is the flow rate of the thoracic duct? | The thoracic duct carries 1.5–4 L of fluid per day.<br>It drains the left hemithorax, left arm, left half of the head, and everything below the diaphragm – comprising approximately 80% and 90% of the lymph from the body. |
| Which regions are drained by the right lymphatic duct? | The right lymphatic duct drains the right hemithorax, right arm, and right half of the head.<br>It drains into the junction of the right internal jugular and subclavian veins. |
| Describe the position of the inguinal lymph nodes. | The inguinal lymph nodes lie inferior to the inguinal ligament, and are divided into superficial and deep nodes by the fascia lata and cribiform fascia.<br>The superficial nodes lie within a triangle created by the inguinal ligament, sartorius, and adductor longus and drain to the deep inguinal nodes through the saphenous hiatus and the cribiform fascia.<br>The deep inguinal nodes lie medial to the femoral vein. |

## Relevant Materials

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| What lymphatic indicator dyes are used to opacify pedal lymphatic vessels during pedal lymphangiography? | Methylene blue or 1% isosulfan blue may be injected in the web spaces of the toes. |

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| What type of contrast medium should be used to opacify the lymphatic vasculature during lymphangiography? | Nonionic, oil-based contrast medium should be used to opacify the lymphatic vasculature as water-soluble contrast medium will leak out of the ducts.<br>Currently, the only commercially available contrast medium for this purpose is Lipiodol. |
| What needle is used for percutaneous abdominal access of the cysterna chylii? | A flexible 21–22 gauge needle (Chiba) with inner stylet, usually 15–20 cm long |
| What wire is used to access the thoracic duct or large retroperitoneal lymphatic trunks? | A stiff, 0.018 inch microwire (e.g. V-18, Transcend, etc.) |
| What catheter is initially used to access and embolize the thoracic duct? | A range of 1.9–3.0 Fr microcatheters may be used. |
| What materials may be used to embolize the thoracic duct? | Microcoils and n-Butyl-2-cyanoacrylate (NBCA) glue are most commonly used.<br>Coils are typically used alone or as a matrix upon which the glue polymerizes. |

## General Step by Step

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| What antibiotic prophylaxis is necessary prior to the procedure? | Gram positive coverage (e.g., cefazolin or clindamycin) prior to dorsal pedal lymphangiography as prophylaxis against skin flora<br>Gram negative coverage (e.g., levofloxacin or second- or third-generation cephalosporins) prior to abdominal puncture as prophylaxis against gastrointestinal flora |

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| What scout images are necessary prior to lymphangiography? | Because early opacification of small lymphatic channels can be subtle, scout images of the chest and abdomen, including obliques, should be obtained prior to lymphangiography. |
| Describe dorsal pedal lymphangiography. | Dorsal pedal lymphangiography is performed by injecting a suitable dye (see above) and cutting down on the lymphatic vessels of the foot. Once skeletonized, they are cannulated with a 30-gauge needle.<br>Lipiodol is infused at a rate of 5–8 mL/hr up to 15 mL, followed by up to 20 mL of normal saline to facilitate the opacification of the cisterna chylii and thoracic duct.<br>Upon the completion of the procedure, the wound should be closed with vertical mattress sutures to reduce tension on the incision.<br>Massaging the medial leg and thigh can help propel the contrast cephalad and reduce the overall time of the procedure.<br>If unilateral dorsal pedal lymphangiography is performed, the right side is preferred as it is more likely to opacify retroperitoneal ducts that are a safe distance from the aorta for percutaneous access. |

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| Describe transnodal lymphangiography. | Transnodal (a.k.a. intranodal) lymphangiography is performed by using real-time ultrasound guidance and a 22–30 gauge needle to puncture the inguinal lymph nodes at a shallow angle, which reduces the likelihood of needle dislodgement. The needle tip is optimally located at the junction of the cortex and the medulla to prevent contrast extravasation or injection of the vein.<br>3–12 mL of iodinated contrast oil is then hand-injected at a rate of 0.1–0.2 mL/min.<br>As with dorsal pedal lymphangiography, saline can follow the Lipiodol to help advance the contrast column into the retroperitoneum. This is now the more commonly performed technique. |
| What is the maximum recommended dose of Lipiodol during a single procedure? Why? | Keeping the dose to a maximum of 20 mL in adults reduces the likelihood of pulmonary artery embolization. |
| How is the progress of lymphangiography tracked? | The progress of lymphangiography should be monitored by serial, overlapping images to ensure that the entire lymphatic system is imaged. Images should be obtained at 5–10 minute intervals in the leg and thigh (when dorsal pedal lymphangiography is used), 5 minute intervals in the pelvis, and 3–5 minute intervals in the abdomen. |
| What is the location of the percutaneous transabdominal puncture site? | Transabdominal access of the cisterna chyli or thoracic duct is achieved right of midline, 5–10 cm below the xiphoid and cephalad to the transverse colon. The duct is accessed against the anterior vertebral body. |

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| Where else can the thoracic duct be accessed? | When no suitable abdominal targets can be identified, the thoracic duct may be accessed in a retrograde fashion by direct puncture of a cervical portion of the duct, or through a transvenous approach at the left jugulo-subclavian venous angle. |
| How is the thoracic duct imaged after catheterization? | Digital subtraction lymphangiography is performed by hand injection of <10 mL of a non-ionic iodinated contrast centered on the upper abdomen and chest to show the entire length of the thoracic duct. |
| Describe the process of TDE. | After successful needle puncture and wire access into the thoracic duct, the needle is exchanged for a microcatheter above the level of the leak (when possible) and multiple coils are deployed across the leak. Thereafter, the embolization can be augmented with a liquid embolic agent, most commonly glue. |
| What is TDD? | Thoracic duct disruption is a misnomer, as the process is typically performed on small retroperitoneal lymphatic ducts and their associated collaterals.<br>It is the process of probing, twisting, and twiddling a needle to macerate the retroperitoneal lymphatic vessels, producing an inflammatory reaction and a small hematoma.<br>This ultimately slows lymphatic flow through the duct. Thoracic duct disruption should be used if the lymphatic ducts cannot be successfully cannulated and embolized. |

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| How should patients be followed after the procedure? | Initially, it is easiest to follow the output of chyle from a drain, if present.<br>Once the drain has been removed, serial chest radiographs will reveal the re-accumulation of chylothorax, if any. |

## Complications

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| What minor complications have been reported because of attempted lymphangiography and thoracic duct embolization? | While some authors have reported no minor complications in their patient cohort, others have reported asymptomatic glue embolization of the pulmonary artery, asymptomatic glue embolization of the portal vein, leg edema, pedal suture dehiscence and wound infection (where dorsal pedal lymphangiography was used), bile leakage and perihepatic hematoma (where transhepatic access of the cisterna chyli is employed), shearing of guidewire with retained fragments in the retroperitoneum, hematoma at the percutaneous access site, periaortic hematoma, and chronic diarrhea.<br>The acute complication rate is 2–6%, while the long-term complication rate is as high as 14%.<br>Needle puncture of interposed viscera and the aorta have both been described, but often do not lead to clinically significant complications. |

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| What major complications have been reported because of attempted lymphangiography and thoracic duct embolization? | While some authors have reported no major complications in their patient cohort, others have reported symptomatic glue embolization to the pulmonary artery, pedal wound infection (where dorsal pedal lymphangiography is performed), venous thromboembolism, cerebral embolization, and death. |

## Landmark Research

Itkin M, Nadolski GJ. Modern techniques of lymphangiography and interventions: current status and future development. *Cardiovasc Intervent Radiol*. 2018; 41:366-76. doi: https://doi.org/10.1007/s00270-017-1863-2.

- Dynamic, contrast-enhanced MR lymphangiography (DCMRL) is the process of using transnodal lymphangiography to deliver gadolinium-based contrast into the central lymphatics prior to MR imaging.
- Ongoing research suggests that TD access and drainage may be useful to induce cellular immunodeficiency to treat organ rejection or autoimmune disease, to harvest lymphocytes for autologous transplant, as an acute therapy to remove excess fluid in the setting of heart failure or hepatic cirrhosis, and to reduce the delivery of toxic metabolic products from the intestine to the lungs to avoid "gut-lung syndrome."

## Common Questions

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| What is the incidence of chylothorax? | The incidence of chylothorax is estimated at 1/6000 hospital admissions, and is reported as high as 11.8% post-esophagectomy. |

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| What size must a lymphatic duct be to warrant attempted catheterization? | Most ducts > 2 mm in diameter can be successfully catheterized. |
| Why is transnodal lymphangiography superseding dorsal pedal lymphangiography as the preferred technique? | Transnodal lymphangiography is less technically demanding, does not require a specific needle or injector, carries a lower risk of needle dislodgment, requires neither a skin incision nor sutures, and reduces the volume of contrast and length of the procedure since the leg lymphatics are excluded. |
| What are the four lymphangiographic presentations of non-traumatic chylous effusion, and how do their clinical success rates with TDE differ? | The four lymphangiographic presentations of non-traumatic chylous effusion are (1) normal thoracic duct, (2) occlusion of the thoracic duct, (3) failure to opacify the thoracic duct, and (4) extravasation of chyle. The clinical success rates of thoracic duct embolization given these lymphangiographic presentations are 16%, 75%, 16%, and 50%, respectively. |
| How long does the procedure, from lymphangiography to successful thoracic duct embolization, usually take? | With normal anatomy and an experienced operator, thoracic duct embolization can take about two hours. The procedure is often longer, necessitating careful attention to patient positioning and comfort at the outset. Consider placing a wedge beneath the patient's back or head for comfort. |
| What evidence suggests that the procedure has or will succeed? | The ability to catheterize the thoracic duct or retroperitoneal lymphatic ducts is correlated with a higher cure rate. A reduction in chylous output to 45% of daily pre-procedural volume 24 hours after the procedure has also been correlated with clinical success. |

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| What is the clinical success rate of lymphangiography alone for chylous effusion? | Clinical success rates of 37–71% have been reported for lymphangiography alone in the setting of traumatic chylous effusions with a daily output no greater than 500 mL/day and no identifiable leak on fluoroscopy.<br>The median time to resolution is approximately 14 days. |
| What is the clinical success rate of lymphangiography and TDE for chylous effusion? | When used for traumatic chylous effusion, the clinical success rate of lymphangiography and thoracic duct embolization has been reported between 72% and 91%.<br>The median time to resolution is approximately 3 days. |
| What is the clinical success rate for lymphangiography and TDD for chylothorax? | The clinical success rate of transnodal lymphangiography and TDD is not as high as that of TDE, and has been reported in the range of 13–74%.<br>The median time to resolution is approximately 7 days. |
| What are the benefits of TDE or TDD for chylous effusion? | TDE or TDD can be performed under local anesthesia and conscious sedation, avoiding the risks of general anesthesia.<br>Thoracic duct opacification can help identify anomalous lymphatic vessels that may also contribute to an effusion. All of the contributing vessels can then be embolized directly.<br>The morbidity and mortality of percutaneous techniques is generally less than that of surgical intervention and therefore can be performed immediately upon the identification of a chylous effusion, without waiting to see if the effusion will resolve with conservative management. |

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| When TDE has been reported to fail, why does it fail? | TDE fails when there is inadequate filling of the lumen of the duct with embolic agents. Embolization should be performed to stasis to minimize this possibility. Large body habitus and operator inexperience can also contribute to an unsuccessful procedure, as they reduce the likelihood that the lymphatic ducts can be successfully catheterized. |
| Does chyle clot, like blood? | Chyle can clot as well as blood, but does so more slowly. Like blood, chyle is also subject to coagulopathy when deficient in its coagulation proteins. |
| How does TDE differ in pediatric patients? | The procedure time is often less, as the volume of contrast necessary for an adequate lymphangiogram is less (0.5–10 mL) and the transit of contrast into the retroperitoneal lymphatics is faster. Shorter needles and microcatheters may also be necessary for embolization, given the smaller AP diameter of a child. |

## Further Reading

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# Part X
# Pediatrics

# Chapter 55
# Pediatrics – Central Venous Access

**Maegan Kellie Garcia Lazaga and Harris Chengazi**

## Evaluating the Patient

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| When are laboratory tests required prior to central venous access? | Laboratory tests are required if a patient has a bleeding diathesis or uncorrectable coagulopathy. |
| How long should patients be kept nothing by mouth (NPO) prior to sedation? | |

| | **Solids and nonclear fluids**[a] | **Clear fluids** |
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| Children <6 months old | 4–6 hours | 2 hours |
| Children 6–36 months old | 6 hours | 2–4 hours |
| Children >26 months old | 6–8 hours | 2–4 hours |

[a]includes milk, formula, and breast milk

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| What are the goals of sedation and anesthesia? Which patients are candidates for general anesthesia? | The goals for both sedation and anesthesia are anxiety relief, pain control, minimizing psychological trauma, and maximizing potential for amnesia and control of excessive movement. During procedures, patients should remain relatively motionless for the safest possible outcome. This outcome can be achieved with various levels of sedation, as well as general anesthesia, depending on the length of procedure, degree of motion control, and ability of the child to remain still with minimal sedative. Patients may specifically require general anesthesia with endotracheal intubation due to the need for intermittent breath holds during the procedure or when there is risk for vasospasm and controlled hypercarbia can help promote vasodilation, such as in cerebral angiography and embolization. |
| When would you use femoral access as primary access? | Femoral access would be first choice in neonates without umbilical venous access, congenital heart disease, emergent access, SVC venous thrombosis, prior surgical intervention, and overlying burns/infection. |
| Why is venous access not performed at the antecubital fossa? | Venous access is not performed in the antecubital fossa secondary to the superficial nature of the access location and final location of the catheter at the elbow joint. This position of the catheter increases the risk of phlebitis and mechanical injury to the catheter, which predisposes to catheter fracture and dysfunction. |
| What clinical history would preclude the placement of a femoral central venous catheter? | Renal disease, given that the possibility of future renal transplant precludes placement of a femoral catheter (prevention of iliac vein injury or thrombosis for future transplant renal vein anastomosis). |

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| Where is the preferred location of the tip of a catheter placed from an upper extremity vein in both subclavian and internal jugular approach? | The preferred location of the catheter tip for these approaches is the entrance to the right atrium (cavoatrial junction). |
| How do you determine if the catheter tip is at the cavoatrial junction using fluoroscopy? | The catheter tip is located at the cavoatrial junction on a posterior-anterior view of the chest when it is approximately two vertebral bodies below the level of the carina. |
| Where is the preferred location of the tip of a catheter placed from a common femoral approach? | The preferred location of the catheter tip for this approach is within the infrarenal IVC or between the diaphragm and the inferior third of the right atrium, below the seventh thoracic interface. |
| Why is catheter tip position important in central venous access? | Appropriate catheter tip position makes the catheter less prone to malposition related to respiratory motion and patient positioning. Appropriate catheter tip position also helps prevent catheter occlusion against the lateral walls of the vessel, endothelial injury, and perforation of the vessel wall by the catheter. |

## High Yield History

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| Name some common conditions which may require long-term central venous access. | Cystic fibrosis, malignancy requiring chemotherapy, renal disease, short gut syndrome, hemophilia, and sickle cell disease. |

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| For each type of central venous access (tunneled and non-tunneled central venous catheters, venous ports, PICCs) what length of time of infusion is usually required? | |
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| Non-tunneled central venous access | < 7 days |
| Peripherally inserted central venous catheter (PICC) | 2 weeks to > 3 months |
| Tunneled central venous catheter | 2 weeks to > 3 months |
| Venous port | Intermittent use for > 3 months |

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| What are common findings on ultrasound denoting acute, subacute, and chronic thrombus within a vein? | Acute thrombus (< 14 days) – low echogenicity, distended vein, and loss of compressibility<br>Subacute thrombus (2 weeks to 6 months) – increased/variable echogenicity, reduction in vein caliber, restoration of luminal flow and thrombus adherence to wall, and development of collaterals<br>Chronic (> 6 months) – wall thickening, echogenic intraluminal post-thrombotic scarring, valve abnormalities with or without reflux, and development of collaterals |
| In a patient with a history of multiple prior central venous catheters, the preferred pathways for access may not be available for use due to thrombosis, fibrosis, or venospasm and collateral pathways may need to be used. What imaging studies may be helpful for planning future sites of central venous access if needed? | The types of imaging studies which can be helpful for planning central venous access in those with complex access histories includes ultrasound, magnetic resonance angiography, CT, or diagnostic fluoroscopic venogram. |

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| What are some alternative access sites for central venous access when the central venous pathways are occluded? | Transbrachiocephalic access, transhepatic access, and translumbar access. |

## Indications/Contraindications

| What are common indications for the various types of central venous access (tunneled and non-tunneled central venous catheters, venous ports, PICCs)? | |
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| Non-tunneled central venous access | Urgent/emergent vascular access<br>Fluid/electrolyte resuscitation<br>Antibiotic therapy<br>Hemodialysis/apheresis |
| Peripherally inserted central venous catheter (PICC) | Antibiotic therapy<br>Hyperalimentation<br>Long-term fluid/electrolyte therapy<br>Venous blood draws |
| Tunneled central venous catheter | Chemotherapy<br>Hyperalimentation<br>Antibiotics<br>Chelation therapy<br>Long-term fluid and electrolyte therapy<br>Hemodialysis/apheresis |
| Venous port | Chemotherapy<br>Hyperalimentation<br>Long-term fluid and electrolyte therapy |

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| What is the purpose of the "cuff" in a tunneled central venous catheter? | The Dacron cuff promotes tissue ingrowth onto the catheter, securing the catheter in the tunnel. |
| Why would a patient need a tunneled, cuffed central venous catheter instead of a PICC? | PICCs do not have a cuff and are susceptible to accidental dislodgement or malposition by the patient or caregiver during dressing changes. Tunneling a central venous catheter also provides a barrier to infection. |
| What is a relative contraindication for central venous access? | There are few contraindications to central venous access. Uncorrectable coagulopathy is a relative contraindication and the procedure is still often attempted as these patients often are seriously ill and require central venous access for treatment. Platelet or fresh frozen plasma administration can be utilized as necessary at the time of the procedure. |
| If a patient has symptomatic bacteremia or sepsis, should a tunneled central venous line be placed? | In general, tunneled central venous access should be delayed until the patient has received antibiotic therapy and there have been 48 hours of no growth on blood cultures. If emergent or urgent central venous access is desired, a temporary, non-tunneled central venous catheter can be placed. |

## Relevant Anatomy

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| Which vein should you avoid using for central venous access? | The subclavian vein should be avoided for central venous access. The subclavian vein is the final common pathway from the ipsilateral extremity to the heart. Additionally, accessing the subclavian vein is associated with the highest risk of complications, including arterial puncture, thrombosis, pinch-off syndrome, and pneumothorax. |
| Which vein is the preferred access for an upper extremity PICC? | The preferred access for upper extremity PICCs is the basilic or brachial veins as they are the largest and most accessible veins with the straightest course. |
| In young children, the terminal arch of the cephalic vein is 1–2 French sizes smaller than the proximal cephalic vein. Why is this important in the placement of upper extremity PICCs? | The smaller caliber of the terminal segment of the cephalic vein forms a terminal "C" or "Z" shape, making navigation from the cephalic vein into the subclavian vein challenging. This "infantile" configuration can require more advanced techniques to navigate, including fluoroscopic road mapping, directional catheters, and angled or glide wires. |
| What embryological process forms the cavoatrial junction? | The absorption of the right horn of the sinus venosus and the remnant of the septum secundum forms the cavoatrial junction. |
| If the left anterior cardinal vein does not obliterate during development, what is the resulting variant anatomy? | If the left anterior cardinal vein does not obliterate during development, a persistent left-sided SVC can result. Catheterization of this vein will appear to course parallel to the spine along the left mediastinal border into the heart. This look can be mistaken for arterial course and it is important to keep persistent left-sided SVC in the differential. |

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| Where does a persistent left-sided SVC commonly drain into? | 80–90% of persistent left-sided SVC drain into the right atrium via the coronary sinus. 10–20% of persistent left-sided SVC drain into the left atrium. |

## Relevant Materials

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| What size wire is able to pass through a 24-gauge needle? | 0.014 inch. |
| What is the difference between a tapered and a non-tapered catheter? | Tapered catheters have ends which taper to the size of the guidewire at their insertion and do not require a peel-away sheath. Non-tapered catheters have a higher friction coefficient and usually require a peel-away sheath for insertion. Non-tapered catheters are also sometimes harder to insert over a guidewire than tapered catheters. |
| What determines the number of lumens that should be selected? | The catheter with the fewest lumens and smallest internal diameter that will satisfy the clinical need is used. This is because the greater number of lumens decreases the cross-sectional area of the catheter and decreases flow within that lumen. This makes blood return more difficult in smaller catheters, increasing the potential for catheter dysfunction. |
| In general, what French sized catheter is used for children less than 10 kg? | In general, for children weighing less than 10 kg, a catheter size of 3-Fr or less is utilized. There are multiple sizes of catheters ranging from 1.1 to 2.6-Fr which can be utilized. Choice in catheter size should be based on infant weight and clinical condition. For very small infants, specialized techniques for access of vessels may need to be used such as a double wall puncture followed by retraction. |

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| In general, what French sized catheter is used for children greater than 10 kg? | 4-Fr. |
| In general, how many lumens and what diameter should be picked? | The fewest number of lumens with smallest internal diameter satisfying the clinical need should be chosen. |
| In general, dialysis or apheresis catheters are what size? | 7-Fr to 14-Fr. |
| In patients not receiving sedation or anesthesia, what medication aside from injectable lidocaine can be used for pain relief? | EMLA cream (topically applied anesthesia). |
| What is the general limit for contrast administration in pediatric patients in mL/kg? | 5 mL/kg. |
| What type of ultrasound probe should be used? | Linear high-frequency transducer with a small footprint. |

## General Step by Step

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| Why would an operator place a patient in 10–15 degrees of Trendelenburg prior to placing an internal jugular vein approach central venous catheter? | This position fills the jugular vein more prominently, allowing the vein to be punctured with less risk to the surrounding structures, and decreases the risk of air embolus. |

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| What should a catheter be inspected for following removal? | Removed catheters should be inspected for defects in the catheter and appropriate length to evaluate for fracture and distal embolization. If infection is suspected, some institutions submit the removed catheter tip for laboratory evaluation with stain and culture. |
| What most commonly causes vasospasm when inserting a PICC? | Vessel trauma with a wire. |
| What are some options to treat venospasm that will not allow a catheter to pass forward in the vessel? | Some techniques to treat venospasm include reducing the size of the catheter by one French size, waiting for the venospasm to resolve, infusing a small amount of sterile saline to allow passage of the catheter, or administering pharmacologic agents such as nitroglycerine, papaverine, priscoline, or calcium channel blockers. |
| Why is a port "heparinized" or "packed with heparin" and what is the concentration of the heparin solution in U/mL? | A port reservoir is filled with heparinized saline at the time of placement and after any time it is accessed to prevent thrombus and occlusion. The concentration of heparin solution utilized is 100 U/mL |
| What maneuvers can be performed if the catheter is coiled within the proximal venous system before removal and replacement? | Flush technique – A 3–5 mL syringe filled with sterile saline is used to forcefully inject the catheter to push the catheter into the appropriate position. |
| How can you position the patient to minimize post-procedural bleeding? | Elevate the head of the bed 15–45 degrees, reverse Trendelenburg or sitting position. |

## Complications

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| What is the treatment for phlebitis? | Warm compress and time, NSAIDs if needed. |
| What constitutes catheter dysfunction? | Occlusion with inability to flush or loss of blood return and pain during flushes or administration of fluids and medications. |
| What is the problem if the catheter flushes but is unable to return blood? | Ball-valve mechanism at the tip due to wedging of the catheter tip against the wall, tip thrombus, or fibrin sheath formation. |
| What is a fibrin sheath and how do you fix it? | A fibrin sheath is a matrix of cells and debris that forms around catheters propagating from the vein entry site towards the tip of the catheter. Generally, this is managed with catheter removal or exchange with or without balloon maceration of the fibrin sheath or installing a small dose of fibrinolytic agent into the catheter. Stripping of the fibrin sheath from a separate access may be successful, though it is usually reserved for patients who fail other methods of management. |
| If catheter fracture is suspected, what should be done? | If fracture is suspected, diagnostic venogram through the indwelling catheter should be performed to evaluate for extravasation along the catheter course, obvious fracture, and embolization of fractured catheter fragments. If fracture is detected, the catheter should be carefully removed under fluoroscopy. If there is an embolized catheter fragment, this can be removed under fluoroscopic guidance with a snare. |
| What is the treatment for tip thrombus? | A trial of thrombolytic therapy can be used (tissue plasminogen activator (tPA), alteplase). |

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| What is the dose of tPA utilized to treat tip thrombus? | The initial dose of tPA is 0.5 mg left in the catheter for 30 minutes to 4 hours. After the initial dwell time, the catheter is aspirated to evaluate for reestablishment of blood flow. This can be repeated for a second dose of 1 mg and for a third dose of 2 mg. Alternatively, a small dose of tPA such as 2–5 mg in 50–100 cc of saline can be infused over 30 minutes (doses and time vary). |
| What is pinch off syndrome? | Narrowing/compression of the catheter as it courses between the clavicle and first rib. This complication is seen with subclavian vein approach central venous access and may lead to mechanical malfunction and possible fragmentation and distal embolization of the line. |
| If you hear a large sucking sound while placing a central venous catheter, what should you instruct the patient to do? What has happened? | This sound is heard when an air embolism has occurred. The patient should be turned to lay on their left side in left lateral decubitus position. This positioning traps the air within the anti-dependent right atrium. |
| What organisms are most likely the cause of catheter related infection? | Coagulase positive and negative staphylococci. |

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| What should be done for an infected central venous line? | The course of action with an infected central venous catheter depends on the type of catheter placed. Most catheter-related infections can be treated with antibiotics without removal of the catheter. Catheters infected with pseudomonas and fungal infections often require catheter removal. Tunneled catheters that are infected with the infection of the subcutaneous tunnel most likely need to be removed. If there is septicemia or septic thrombophlebitis, the line needs to be removed. |

## Landmark Research

**Cathflo Activase Pediatric Study** Blaney M, Shen V, Kerner JA, Jacobs BR, Gray S, Armfield J, Semba CP, CAPS Investigators. Alteplase for the treatment of central venous catheter occlusion in children: results of a prospective, open-label, single-arm study (The Cathflo Activase Pediatric Study). Journal of Vascular and Interventional Radiology. 2006 Nov 1;17(11):1745–51.

- 310 patient multicenter prospective, single-arm study evaluating the use of alteplase in pediatric patients for the treatment of central venous catheter and port occlusion.
- With a maximum of two instillations of alteplase for a maximum dwell time of 120 minutes, the cumulative rate function restoration was 82.9% with similar rates of function restoration among all types of catheters studied.
- The primary outcome was the rate of intracranial hemorrhage secondary to alteplase administration (0). Secondary outcome was targeted serious events (major hemorrhage, thrombosis, embolic event, sepsis, catheter-related complication). Three cases of sepsis, 4 catheter-related complications (rupture) for a total of 7 serious events occurred in 8 patients (2.6% incidence).

## Common Questions

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| If the central drainage pathways are occluded, by what collateral pathway does drainage normally occur? | Hemiazygos and azygous veins. |
| About how long does it take for significant tissue ingrowth to occur around the cuff in a tunneled catheter? | 10–14 days. |
| What is the preferred exit site for a tunneled catheter? | Anterolateral chest wall. |
| What is an important consideration for the exit site and tunnel for a tunneled catheter or port placement location in young females? | Injury to the breast bud which can result in abnormal breast development. |
| What is the name of the needle used to access a port? | The needle used to access a port is a "non-coring" hollow needle with a beveled tip called a Huber needle. A non-coring needle is used in order to prolong the life of a port's silicone septum thereby prolonging the life of the port reservoir. |
| Why might a port be placed in the upper arm, forearm, or leg? | Ports can be placed in the extremities in older children who do not want a scar or bump on their chest. Other sites of port placement that have been described include the upper arm, forearm, or upper leg. |
| Why would you avoid femoral access in neonates and infants? | Higher likelihood of infection from the diaper and restriction of patient movement. |

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| What is Paget–Schroetter's disease? | Effort thrombosis of the axillary and/or subclavian vein, the venous equivalent of thoracic outlet syndrome |

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# Chapter 56
# Pediatrics – Enteral Access

**Harris Chengazi and Maegan Kellie Garcia Lazaga**

## Percutaneous Gastrostomy/Gastrojejunostomy

### *Evaluating the Patient*

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| What are the most common indications for feeding tube access? | Inability to swallow, inadequate caloric intake for normal growth (failure to thrive), and abnormal gastric function requiring chronic drainage. |
| When is percutaneous feeding tube placement preferred over nasally advanced feeding tubes? | When access is required long term (greater than ~6 weeks). |

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| What is the advantage of using percutaneous feeding tube access over parenteral nutrition? | Percutaneous feeding tube access generally has fewer complications than parenteral nutrition. Complications of parenteral nutrition include catheter related infection, catheter-associated thrombosis and embolism, and sequela of hyperalimentation (fatty liver disease, cholestasis, bowel atrophy, and electrolyte and metabolic disturbances). |
| What are the major types of percutaneous enteral feeding access? | Gastrostomy and gastrojejunostomy. |
| When is a gastrojejunostomy preferred over a gastrostomy for feeding access? | Gastrojejunostomy is preferred when the patient has delayed gastric emptying or evidence for gastroesophageal reflux with aspiration. |
| What are the contraindications for percutaneous gastric access? | Uncorrectable coagulopathy, clinical instability, and anatomic limitations (e.g., micrognathia, microgastria, and intervening anatomy including bowel, liver, and epigastric artery). |

## Relevant Anatomy

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| Where is the ideal access for percutaneous gastric access? | The ideal window for percutaneous access is at the lateral margin of the rectus abdominis muscle, below the costal margin. |
| What vessels must be avoided during gastric access? | The epigastric arteries must be avoided during percutaneous gastric access. |
| What organs must be avoided during percutaneous gastric access? | The left hepatic lobe and the transverse colon may overlie the stomach and limit percutaneous access window. |

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| How is the percutaneous tract ideally oriented? | The percutaneous tract should be oriented toward the pylorus. In gastrostomy patients, this orientation facilitates conversion to gastrojejunostomy when indicated. In gastrojejunostomy, this orientation reduces the likelihood of tube malposition in the stomach. |
| What is the ideal placement for the tip of a jejunostomy tube? | Just distal to the ligament of Treitz. |

## Pre-procedure and Technical Considerations

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| What are the two approaches to the placement of percutaneous gastrostomy/ gastrojejunostomy? | Percutaneous gastric access can be performed in both anterograde and retrograde fashion. These are described in further detail in the 'step-by-step' section of the chapter. |
| What are the advantages of retrograde access compared to anterograde access? | Can be performed without general anesthesia and smaller caliber tubes can be placed, which may be more comfortable for the patient. |
| What are the disadvantages of retrograde access compared to anterograde access? | Retrograde access is typically performed with a smaller caliber tube which increases the likelihood of tube obstruction. The smaller tubes are also more mobile which increases the likelihood of dislodgement. |
| What can be administered to aid in the localization of the colon? | Thin barium administered via nasogastric tube 4–6 hours prior to procedure, or thin barium or water-soluble iodinated contrast administered via enema. |

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| What should be done to ensure avoidance of critical structures during the procedure? | Prior to the procedure, cross-sectional imaging should be reviewed (if available) to assess for anatomy that intervenes between the stomach and cutaneous tissues. At the time of the procedure, ultrasound should be performed to delineate the left hepatic lobe and epigastric arteries. A fluoroscopic image after barium administration should also be obtained to confirm the position of the transverse colon. |
| When might a sub-xiphoid approach be preferred? | A sub-xiphoid approach is preferred in patients with high stomach, midline stomach, or transverse stomach. |
| What are the limitations to a trans-rectus abdominis approach? | The epigastric arteries course within the rectus musculature and must be avoided. After tube insertion, the rectus musculature can cramp and is associated with greater discomfort after the procedure. |
| In general, how big should the skin incision at site of access be? | The skin incision should be larger than the tube being inserted to avoid the risk of pressure necrosis, usually about 1.5–2 cm. |
| What fluoroscopic projection is helpful to confirm appropriate position within the stomach? | A lateral fluoroscopic projection can demonstrate the stomach against the anterior abdominal wall, and contrast can be confirmed within the lumen. |

## Relevant Materials and Equipment

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| When are prophylactic antibiotics indicated? | Prophylactic antibiotics are indicated in immunocompromised patients or those with a history of post-procedural infections. |
| What size feeding tube is typically used for gastric insufflation? | 8–10 French nasogastric feeding tubes are sufficient for gastric insufflation. |
| What medication can be given to improve gastric distension during insufflation? | Glucagon closes the pylorus and limits the progression of gas into the small bowel by decreasing peristalsis. Weight-based dosing of Glucagon is typically 0.02–0.03 mg/kg/dose, with a maximum dose of 0.5 mg in patients under 20 kg and 1 mg in patients over 20 kg. |
| What size gastrostomy tube is typically placed in an anterograde fashion? | 14–16 French. |
| What size gastrostomy tube is typically placed in a retrograde approach? | 8.5–12 French. |
| What size tubes are generally used for gastrojejunostomy? | 16–18 French gastrostomy tube with a 6–9 French jejunostomy tube. |
| What is used as local anesthetic for the skin entry site? | 1% Lidocaine, administered via a 27–30G needle. |
| What sized needle is generally used to puncture the abdominal wall and stomach? | An 18-gauge puncture needle. |
| What type of guidewire is typically used? | A 0.035-inch non-Teflon-coated guidewire. |

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| What special equipment is required for an anterograde placement? | A nitinol snare is used to retrieve the percutaneously placed guidewire for tube advancement. The 0.035-inch guidewire is also longer than in a retrograde approach. |
| What special equipment is required for a retrograde placement? | A gastropexy suture/anchor set to affix the stomach to the anterior abdominal wall. |
| What is typically used to dilate the skin tract? | A telescoping dilator, a serial dilator set, or a balloon can be used to dilate the skin tract. |
| How is a jejunostomy tube typically placed? | Jejunostomy tubes are usually placed coaxially, via a gastrostomy tube. |

## Post-procedure Care and Maintenance

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| How is a patient typically monitored post procedure? | Usually for about 2 hours or return to baseline after anesthesia. |
| When can tubes be used for feeding? | A tube can usually be used the day after the procedure, as long as bowel sounds have returned. |
| How are amounts and types of feeds determined? | Feeding schedule and dosing is usually done with the assistance of a dietary consultation, taking into account the patient's size, comorbidities, and caloric requirements. |
| How are initial feeds administered and augmented? | The patient is usually advanced from clear liquids to higher calorie solutions via a continuous pump. Once this is tolerated, the rates can be escalated to allow for longer periods of time off the pump each day, while maintaining caloric intake. |

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| When should retention sutures applied for retrograde approach be removed? | Retention sutures should be cut after 14 days, if they do not release spontaneously. |
| How long does a tract usually take to mature? | About 4–6 weeks, the tube should not be electively exchanged during this time to promote maturation. |
| When can a patient resume activities, such as swimming and bathing? | After complete tract maturation. |
| How often should the maintenance or exchange of the G-tube be performed? | Typically, feeding tubes can be serviced only on an as-needed/elective basis. Small caliber tubes may require routine servicing at 6-month intervals. |
| What are indications for early tube exchange? | Leakage, blockage, and dislodgement. |
| What should be given to the parents of a patient in the event of a tube dislodgement? | A Foley catheter one size smaller than the gastrostomy tube should be available to the parents. The foley catheter can be placed in the tract to ensure patency until intervention can be performed. |
| What is a low-profile G-tube? | A low-profile G-tube has a set distance from the external button and the internal balloon, minimizing the external portion of the feeding tube. There is no adjustable flange, as the low-profile tube is specific to specific tract length. |
| When can a low-profile G-tube be placed? | Low profile G-tubes require a mature tract, so they are typically placed after 6 weeks form initial placement. A mature tract allows for the measurement of stoma length for appropriate sizing of the low-profile tube. |

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| Why do patients and referring providers prefer low-profile G-tubes? | Low-profile tubes are more comfortable and less likely to be pulled out by the patient. |

## General Step by Step: Antegrade Approach

1. Administer barium orally or via enema prior to the procedure to aid in localization of colon.
2. Identify the liver and spleen (if enlarged) under ultrasound and mark the skin. The costal margin should also be delineated.
3. Insert nasogastric and orogastric tubes.
4. Exchange orograstic tube for snare.
5. Inflate stomach manually or with CO2 via nasogastric tube.
6. Under fluoroscopy, puncture the stomach, avoiding the previously delineated anatomy.
7. Insert and snare a guidewire, and retrieve via the oral cavity.
8. Advance gastrostomy tube over wire via the mouth and pull it through the percutaneous access site. Inject contrast with orthogonal views to confirm position.
9. Secure the gastrostomy tube with a flange.
10. Coaxially advance jejunostomy tube via gastrostomy tube if required.

## General Step by Step: Retrograde Approach

1. Administer barium orally or via enema prior to procedure to aid in localization of colon.
2. Identify the liver and spleen (if enlarged) under ultrasound and mark the skin. The costal margin should also be delineated.

3. Insert nasogastric tube and insufflate the stomach.
4. Under fluoroscopic guidance, advance gastropexy sutures into the stomach and secure them.
5. Puncture the stomach, inject contrast to confirm position, and advance a wire to secure access.
6. Advance a gastric tube over wire or via peel-away sheath.
7. Inject contrast with orthogonal views to confirm position.
8. Secure the gastrostomy tube with a flange.

## Complications

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| What are the signs and symptoms of peritonitis? | Fever and abdominal pain. |
| What are some potential etiologies for peritonitis? | Colonic injury, leakage of gastric contents, and tube malposition. |
| How should a patient with peritoneal signs be managed? | Tube feeds should be stopped immediately, and broad-spectrum antibiotics should be administered. A fluoroscopic exam should be performed to assess the position of the feeding tube tip. If the tip is malpositioned within the peritoneum, the tube requires removal and replacement. If the tip of the tube is appropriately positioned, peritonitis may be secondary to leakage and tube upsize may be indicated. |
| What imaging studies are most useful to evaluate the tube position? | Contrast-enhanced fluoroscopy or CT of the abdomen can be used to confirm the tube position. |

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| What should be done if a tube is dislodged before the tract matures? | An attempt can be made to cannulate the immature tract; however, this may be technically difficult if the internal retention sutures have dislodged or if wire manipulation results in the creation of a false tract. Fresh placement of the tube is often preferred as the stomach is directly accessed. |
| What should be done if a tube is dislodged from a mature tract? | A Foley catheter should be placed to ensure the patency of the tract. A new tube can typically be placed at bedside without the need for sedation. |
| What factors increase the likelihood of hypoglycemia after Glucagon administration? | Prolonged fasting and use of beta-blockers. |
| What can be given to decrease the likelihood of hypoglycemia after Glucagon administration? | Glucose containing maintenance fluids. |
| What can be done to prevent skin breakdown around the site? | The site should be monitored and cleaned frequently. Absorbent gauze can be placed between the button and the skin. The tube can be rotated 45 degrees daily to avoid pressure effects in the same location. |
| What increases the likelihood of skin breakdown around the access site? | Leakage from the gastrostomy site due to improper tube size, granulation tissue, excessive sweating, and improper hygiene all increase the likelihood of skin breakdown. |

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| How can granulation tissue around the gastrostomy site be managed? | Topical application of silver nitrate. |
| How is a skin site infection managed? | A minor infection can be irrigated with hydrogen peroxide and topical antibiotic cream can be applied. If topical management is unsuccessful, the site should be cultured and oral antibiotics should be administered. If an abscess is present, it can be aspirated or drained percutaneously. |
| How can a can a blocked feeding tube be unclogged? | Forceful injection of fluid via a 5 cc syringe may be all that is required to unclog a tube. If this is unsuccessful, a 3 cc syringe can be attempted. If manual injection is unsuccessful, a flow-switch device can be applied to allow for rapid alternation between injection pressure and suction. If mechanical unclogging is unsuccessful, a solution containing digestive enzymes can be injected to break down the obstructing feed material. |
| If a tube cannot be unclogged, what should be done next? | The tube should be exchanged for a new tube. |
| What can be done to decrease the likelihood of small bowel intussusceptions? | The tube can be trimmed/shortened or exchanged for a different device. |

# Cecostomy

## *Evaluating the Patient*

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| What is the primary indication for cecostomy tube placement? | Fecal incontinence. This may be due to myriad congenital, developmental, posttraumatic, and behavior issues, including Spina Bifida, cerebral palsy, and imperforate anus. |
| What is the benefit of a cecostomy tube? | A cecostomy tube allows for controlled bowel irrigation, allowing for scheduled evacuation. |
| What are some contraindications for cecostomy tube placement? | Nearby VP shunt tip, uncorrectable coagulopathy, or other medical conditions that would increase the risk of procedure or sedation are all contraindications. |
| At what age is a cecostomy tube ideally placed? | Timing is variable, but consensus from parents and patients suggests placement before school age (4–6 years old) is preferred. By this age, parents have usually developed good understanding of their child's bowel behaviors, then children are able to provide some input, and they are at an age where they can develop a routine that helps avoid incontinence in school. |

# Pre-procedure and Technical Considerations

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| What special precautions must be taken with Spina Bifida patients? | Latex allergies are common in Spina Bifida patients, so precautions must be taken. |

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| Does the patient require any bowel preparation? | Yes, a clear liquid diet for 2 days prior to the procedure and oral administration of sodium phosphate solution the night before the procedure. An additional dose of sodium phosphate can be given the morning of the procedure, as needed. |
| What pre-procedural imaging should be performed, and which organs marked? | Ultrasound should be performed to delineate the liver, gallbladder, and urinary bladder. |
| What prophylactic antibiotics are given for the procedure? | Gentamicin, ampicillin, and metronidazole are all given as a single pre-procedure dose. |
| How is the bowel insufflated for access? | The bowel is insufflated via Foley catheter placed in the rectum, with subsequent gas enema. |
| How is the position of the cecum confirmed fluoroscopically? | Intermittent images should be obtained during insufflation. This allows for the identification of redundant loops of bowel that may mimic the cecum. |
| What other structures should be identified via physical exam and fluoroscopy? | The iliac crest and lower costal margin should be identified and avoided. Ventriculoperitoneal shunt tubing should also be identified and avoided if present. |

## Relevant Materials and Equipment

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| Why is Glucagon often administered during cecostomy tube placement? | Glucagon slows bowel motility and prolongs the effects of bowel insufflation. |
| What is used for skin access site anesthesia? | Lidocaine 1–2% administered via a 27–30G needle. |
| What size needle is used to access the cecum? | An 18-gauge puncture needle. |

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| What is the purpose of retention sutures? | To hold the cecum against the anterolateral abdominal wall. |
| What type of guidewire is typically used for cecostomy placement? | A stiff 0.035-inch guidewire. |
| What size tube is typically placed? | An 8.5 French locking pigtail catheter or equivalent. |

## General Step by Step: Retrograde Approach

1. Administer gas enema via rectally placed foley catheter. Intermittent fluoroscopic imaging is essential to identify redundant loops of bowel.
2. Under fluoroscopic guidance, advance plexy sutures and secure the cecum to the anterior abdominal wall.
3. Puncture the cecum with a needle, inject contrast to confirm position, and advance a wire to secure access.
4. Use a fascial dilator to prepare the tract.
5. Advance a locking pigtail catheter over wire, and inject contrast with orthogonal views to confirm position.

## Post-procedure Care and Maintenance

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| Does the patient require additional antibiotics post-procedure? | Yes, the gentamicin and ampicillin should be continued for two days, and metronidazole should be given for 5 days (as an oral medication). |
| How often should the catheter be flushed? | The catheter should be flushed twice a day with 10 mL of saline until the patient can start anterograde bowel irrigation. |
| When can a patient begin anterograde bowel irrigation after cecostomy placement? | Anterograde irrigation can start about 10 days after tube placement. Until that time, the patient should continue their pre-procedural enema regimen. |

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| When should the retention sutures be cut? | At 14 days post-placement. |
| Is there a low-profile tube option for cecostomy? | Yes, there is a low-profile "trap door" option that comes with different tract lengths. These can be exchanged for after about 2 months. |
| How often does a tube need to be exchanged? | As needed for failure, or annually. |

## Complications

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| What should be done if the tube is inadvertently malpositioned outside the cecum? | The tube can be removed and replaced appropriately if tract dilation has not been performed. If the tract has been dilated, the tube should be left in place until the tract matures. Close surveillance for signs of chemical peritonitis should be performed in both situations. |
| How is peritonitis managed? | Discontinuation of enemas and a course of broad-spectrum antibiotics. |
| How common is granulation tissue after cecostomy tube placement? | Granulation tissue is very common and may be seen up two-thirds of patients. This can be managed with silver nitrate cauterization as indicated. |
| What increases the likelihood of tube occlusion or leakage? | The longer a tube goes without exchange, the more likely complications are. |
| How is tube occlusion managed? | If a guidewire can be advanced, the tube can be exchanged over wire. If a guidewire cannot be advanced and the tract is mature, the tube may be removed and a guidewire subsequently placed via the tract (over which a new tube is placed). |

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| How is tube dislodgement managed? | In a mature tract, a Foley catheter can be placed by the patient or parent, and subsequently exchanged for a new tube. If the tract is not mature, the patient should be seen by an interventional radiologist who can make an attempt to access the tract. If these attempts are unsuccessful, a new tube insertion must be scheduled. |

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# Chapter 57
# Vascular Anomalies

**Madeline Leo**

## High-Yield History

| | |
|---|---|
| When are venous malformations usually present? | At birth, with slow growth over time |
| When are lymphatic malformations usually identified? | At birth, or sometimes prenatally on ultrasound |
| What are several periods of life in which vascular malformations are likely to grow? | Puberty and pregnancy - This is believed to be due to effects of hormonal change. |
| Why can venous malformations be painful? | Thrombosis of the lesion can occur due to the slow nature of venous flow, which leads to inflammation and pain. Venous dilation can also contribute to pain. |

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## Evaluating the Patient

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| Describe the appearance of lymphatic malformations on physical exam. | Lymphatic malformations present physically as soft, compressible masses. |
| Describe the physical appearance of venous malformations. | They are soft, compressible, and nonpulsatile. They can be elicited by Valsalva maneuver. Phleboliths are often helpful in distinguishing venous malformations. |
| What imaging modalities can be used to evaluate vascular anomalies? | Ultrasound, CT, MRI, and angiography can all be used to evaluate vascular anomalies. Different studies are useful based on patient anatomy and type of anomaly. |
| Describe the typical imaging appearance of lymphatic, venous, and high-flow malformations on ultrasound, CT, and MRI. | |

| Type | Ultrasound (US) | Computed tomography (CT) | Magnetic resonance (MRI) | Angiography |
|---|---|---|---|---|
| Lymphatic | Anechoic spaces<br>Possible internal septations or debris<br>Minimal flow | Low-attenuation masses<br>Possible fluid levels from low-flow state<br>Possible peripheral enhancement on contrast-enhanced CT | Multi-cystic masses with fluid-type signals on all sequences<br>T2: hyperintense signals<br>T1: hypointense signals<br>Can extend through soft tissue compartments | Can show obstruction, collaterals, or possible lymph leak |
| Venous | Heterogeneous or hypoechoic grayscale appearance<br>Monophasic flow on Doppler | Hypoattenuating masses<br>Dystrophic calcifications sometimes present | T1 iso/hypointense signals<br>Increased fat within lesion can create T1 hyperintense signals<br>Hyperintense signals on T2 (usually preferred sequence) | Venography shows dynamic venous drainage patterns<br>Estimates the amount of sclerosing agent needed |
| AVM | Multiple well-defined anechoic structures on grayscale US<br>Pulsatile venous flow with low resistance arterial flow on Doppler | Typically not performed unless concern for acute bleeding<br>Hypertrophied vessels draining rapidly into outflow vein | Multiple hypertrophied arteries with dilated veins<br>Signal voids on spin echo images<br>Flow related signal on gradient echo sequences | Hypertrophied arteries with rapid shunting into directly connected outflow veins<br>No soft tissue enhancement |

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| What vascular malformation is characterized by well defined, rounded, scattered calcifications within a soft tissue mass? | Venous malformation |
| What property of a vascular malformation can be deduced from visualizing fluid levels on CT? | A low-flow state |
| What malformation is characterized by a "mosaic" pattern on Doppler flow? | An arteriovenous malformation – This is usually the area of the nidus of the malformation. |
| What physical exam finding is typical of an arteriovenous malformation? | Bruit |
| What laboratory finding is elevated in venous malformations? | D-dimer has shown to be elevated. Low fibrinogen level has also been described. |
| What are some clinical syndromes associated with vascular malformations? | Klippel-Trenaunay<br>Parkes Weber syndrome<br>Sturge Weber Syndrome<br>Maffucci syndrome<br>CLOVES (congenital lipomatous overgrowth with vascular malformations, epidermal nevi, and skeletal anomalies) |
| What is Klippel-Trenaunay syndrome? | A combined vascular malformation syndrome, associated with capillary, venous, and lymphatic malformations. There is a characteristic overgrowth of the extremity affected. |

## Relevant Anatomy

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| What are the different general vascular structures that can be involved in vascular anomalies? | Capillaries, veins, arteries, and lymphatics can be involved. Multiple types of structures can be involved in a single lesion. |
| Developmental defects during what processes lead to vascular anomalies? | Embryonic lymphangiogenesis or vascular morphogenesis. |
| Describe the difference between macrocystic and microcystic lymphatic formations. | Macrocystic malformations are composed of cyst spaces >2 cm, and microcystic are composed of spaces <2 cm. |
| What is the typical anatomic distribution of venous malformations? | See below |

| **Body part** | **Prevalence (%)** |
|---|---|
| Head and neck | 40% |
| Extremities | 40% |
| Trunk | 20% |

| | |
|---|---|
| The capillary malformation commonly known as a "port-wine stain"with a distribution over the V1 area of the face is commonly associated with which syndrome? | Sturge-Weber syndrome |
| Where do AVMs most commonly occur? | They are most commonly reported in the extremities and pelvis. They usually expand during adolescence. They can be treated with transcatheter or percutaneous nidal ablation. |

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|---|---|
| Define the "nidus" of an AVM. | The nidus is the area which leads to direct, rapid shunting of arterial to venous flow within an AVM, without a normal capillary network. This is typically the directed area of treatment. The veins are often described as "arterialized." |

## Relevant Materials

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| What is sclerotherapy? | Sclerotherapy is the use of an agent's biologic, physical, and chemical properties to induce a controlled inflammatory response rendering the tissue fibrosed or hardened with drastically different functional capability. |
| What are some ways that sclerotherapy effects target tissue? | Inflammatory response<br>Thrombosis<br>Protein denaturation<br>Cell dehydration |
| Gives some examples of agents used in sclerotherapy. | Ethanol<br>Sodium tetradecyl sulfate (STS)<br>Ethanolamine<br>Hypertonic saline<br>Bleomycin<br>N-Butyl-2-cyonoacrylate (NBCA)<br>OK 432 |
| Identify the relationship between vascular malformation subtypes and some typical types of sclerosants used in treatment. | |

| Type | Agents used |
|---|---|
| LM | Ethanol<br>Doxycycline<br>Bleomycin<br>OK 432<br>STS |
| VM | Ethanol<br>STS |
| AVM | Ethanol<br>NBCA |

| | |
|---|---|
| What is the mechanism of action of STS? | STS causes endothelial damage. Risks of use include pain and skin necrosis. |
| How is STS foam prepared? | A combination of 1 mL 3% STS with 4 mL of air is mixed to produce a foam mixture which can be injected via catheter access. |
| Which agent is a biologic product created as a product from group A strep that causes natural killer cell activation in sclerotherapy? | OK 432 |
| What is the mechanism of action of bleomycin and what is the most feared toxicity complication? | Bleomycin has anti-neoplastic properties, which result in fibrosis secondary to DNA damage. It can be used in the treatment of superficial lymphatic malformations. The most feared toxicity is pulmonary damage or fibrosis. |
| Name some hyperosmotic agents used in sclerotherapy. | Saline and glucose solutions dehydrate cells, but can also carry a risk of causing tissue necrosis. |

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| What is the mechanism of action of n-Butyl cyanoacrylate (NBCA)? | NBCA is an adhesive "glue" agent which polymerizes when exposed to ionic environments through an exothermic reaction, and creates fibrosis. It has been described in the use of certain high-flow malformations with concurrent flow control techniques. |
| What are some additional therapeutic modalities that can be applied in vascular malformations aside from sclerotherapy? | Radiofrequency ablation and laser therapy have been used in the treatment of some vascular malformations. |

## Indications/Contraindications

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|---|---|
| What are some indications for treating vascular malformations? | Indications include pain, hemorrhage, high-output cardiac complications, and malformations that interfere with normal growth. |
| Name some relative contraindications for treating vascular malformations. | Pregnancy, iodinated contrast anaphylaxis, sepsis, acute renal failure |
| Describe the prophylactic treatment of iodinated contrast allergy in children. | Oral prednisone dosed 0.5 mg/kg (max 50 mg) for 3 doses at 13, 7, and 1 hours before a procedure in addition to a 1.25 mg/kg dose (max 50 mg) of diphenhydramine 1 hour before a procedure is the current regimen recommended for a known contrast allergy. |

## General Step by Step

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|---|---|
| Historically, what is the most common treatment approach for lymphatic malformations? | Surgical resection was historically preferred. |
| What medication is administered before treating lymphatic malformations? | Antibiotic administration, due to risk of spontaneous infection, has been used. Dosing recommendations are cefazolin 25 mg/kg in pediatric patients or clindamycin 10 mg/kg if there is concern for penicillin allergy. |
| What pre-procedural lab values are important to obtain prior to performing treatment? | Complete blood count<br>Electrolytes<br>Creatinine<br>Coagulation studies<br>D-dimer |
| Outline the general process for treating a venous malformation. | 1. The patient is sterilely prepped and draped.<br>2. Vascular access is gained into the lesion, with contrast injected to locate the lesion.<br>3. The sclerosant is injected under fluoroscopy guidance.<br>4. The access devices are withdrawn safely.<br>5. A sterile dressing applied.<br>6. Post-procedure care is initiated. |
| What medication can be given to reduce inflammation post-procedure for a low-flow lesion? | A steroid taper for 2 days can help with swelling and inflammation secondary to treatment. |

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| What are important elements of post-procedural care? | Bed rest, depending on if the procedure was for a venous or arterial malformation (six hours for arterial versus two for venous). Pain control is important, and can usually be managed with oral medication. |
| In treating high-flow vascular malformations such as AVMs, what is the goal of treatment and what are some different approaches in achieving this goal? | The goal of treatment is to selectively target the nidus of the AVM, which is described previously. Different approaches of targeting the nidus include:<br>Superselective catheterization of the nidus with subsequent sclerotherapy administration<br>Direct nidus puncture using a percutaneous approach<br>Retrograde sclerotherapy infusion through a venous approach, with balloon-assisted occlusion of the feeding arterial vessel<br>Flow rate and necessary dosage of therapy agent are always estimated before using angiography. |

## Complications

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|---|---|
| What are some complications of sclerotherapy performed for venous malformations? | Erythema and skin breakdown, bleeding, hemoglobinuria, and DVT are all complications which can occur following sclerotherapy. |
| What are complications of treating high-flow malformations? | Non-target embolization can occur, which leads to possible ischemia and damage if the treatment agent goes outside of the intended lesion. Passage of embolic agent to the lungs is also a complication. |

| | |
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| What is the value of using cross-sectional imaging (CT or MRI) as a modality for evaluating lymphatic malformations? | CT can be used to visualize the compression and potential compromise of surrounding anatomic structures, such as the airway. |
| Which sclerosing agent can cause acute pulmonary hypertension? | Ethanol |
| What is a synovial venous malformation? | A venous malformation about a joint that can possibly extend into the joint space and cause sequelae of hemarthrosis |

## Landmark Research

Mulliken JB, Glowacki J. Hemangiomas and Vascular Malformations in Infants and Children: a classification based on endothelial characteristics. Plastic and Reconstructive Surgery. 1982; 69(3): 412–22.

- Vascular anomalies classified into two groups – hemangiomas and vascular malformations.
- Defining characteristic of hemangioma classified as increased mitotic activity in the cells within the lesion.
- Defining characteristic of a malformation is a lesions that shows normal mitotic activity and does not regress throughout life.

ISSVA Classification of Vascular Anomalies ©2018 International Society for the Study of Vascular Anomalies Available at "issva.org/classification" Accessed 24 September 2018.

- The most updated ISSVA classification scheme is broadly divided into vascular tumors (benign vs. malignant) and vascular malformations (further divided into categories of simple, combined, those of major vessels, and those associated with other anomalies).

Merrow AC, Gupta A, Patel MN, Adams DM. 2014 Revised Classification of Vascular Lesions from the International Society for the Study of Vascular Anomalies: Radiologic-Pathologic Update. Radiographics. 2016; 36(5): 1494–516.

- The two general classifications of vascular malformations are low-flow malformations, which include lymphatic and venous malformations, and high-flow malformations.
- Two examples of high-flow malformations are arteriovenous malformation (AVM) and arteriovenous fistula (AVF) – AVMs are associated with syndromes and result in primitive arteries and veins communicating, causing a shunt of oxygenated blood away from target tissues. AVFs are direct communications, which are often created iatrogenically.

Cahill AM, Nijs ELF. Pediatric Vascular Malformations: Pathophysiology, Diagnosis, and the Role of Interventional Radiology. Cardiovascular and Interventional Radiology. 2011; 34(4): 691–704.

- The four stages of arteriovenous malformations based on Schobinger are: 1. Quiescence; 2. Expansion; 3. Destruction; 4. Decompensation.

## Common Questions

| What is the most common type of vascular malformation? | Cavernous venous malformation. In general, the reported prevalence of various vascular malformations is: |
|---|---|
| Venous | 70% |
| Lymphatic | 12% |
| AVM | 8% |
| Combined malformation syndromes | 6% |
| Capillary malformations | 4% |

| | |
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| What is the most common benign vascular tumor in children? | Infantile hemangioma or "strawberry" mark – they are typically not present at birth, but emerge after. They tend to involute over multiple years. Oral propranolol has largely become the treatment of choice. |
| How long after treatment can a patient expect to see a difference in appearance of venous malformation? | Lesions actually might appear worsened and swell in the first 2 weeks, but typically start to improve in 4–6 weeks. |
| How many treatments are usually necessary for vascular malformations? | Treatment course and number of treatments needed is variable and patient-dependent. Some patients only require one treatment, while others may need many depending on the size and symptoms of the vascular malformation. |
| How long should children avoid physical activity post procedure? | 10–14 days. |
| What medical specialties comprise an interdisciplinary team in caring for patients with vascular anomalies? | Interventional radiologists can collaborate with plastic surgeons, orthopedic surgeons, and pediatricians to care for patients with vascular anomalies. |

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# Chapter 58
# Pediatric Genitourinary Interventions

**Ethan J. Speir, C. Matthew Hawkins, and Anne Gill**

## Evaluating the Patient

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| What labs should be ordered prior to any GU intervention? | CBC, PT/INR, and BUN/Creatinine<br><br>For patients undergoing PCN or stent placement, urinalysis, and urine culture may also be considered. |

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| What abnormality should be suspected in infants and children with recurrent UTIs? What is the test of choice for diagnosing this? | Vesicoureteral reflux (VUR). The test of choice is voiding cystourethrogram (VCUG). |
| In a patient with unilateral ureteral obstruction and severe unilateral hydronephrosis, would serum creatinine expected to be low, normal, or elevated? | Normal. |
| Which patients should be considered for general anesthesia? | Children undergoing PCN or stent placement (can be considered for renal biopsy in younger children). |
| Which patients may be considered for IV sedation? | Children undergoing renal biopsy or PCN/stent exchange. |

## High Yield History

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| You are consulted for placement of a PCN in a 3-month-old with hydronephrosis from ureteropelvic junction (UPJ) obstruction. In reviewing the patient's chart, you notice a history of ventricular septal defect and trachea-esophageal fistula. What other birth defects should you suspect? | Suspect VACTERL association |
| | V – Vertebral anomalies |
| | A – Anorectal malformations (e.g., imperforate anus) |
| | C – Cardiovascular anomalies |

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| | T – Tracheoesophageal fistula<br>E – Esophageal atresia |
| You perform a biopsy on renal mass in 4-year-old female. Pathology is consistent with Wilms tumor. What associated syndromes may be found when reviewing the patient's history? | WAGR (aniridia, GU abnormalities, mental retardation) |
| | Denys–Drash syndrome (gonadal dysgenesis, nephropathy) |
| | Beckwith–Wiedemann syndrome (hemihypertrophy, macroglossia) |
| What aspects on a patient's history increase their risk of UTI? | Young age (males <1-year-old, females <4 years-old), uncircumcised males, white race, incomplete voiding due to neurogenic bladder (e.g. spina bifida), and anatomic urinary obstruction (posterior urethral valves, extrinsic compression of the ureters, nephrolithiasis, etc.) |
| What aspects on a patient's history increase their risk of nephrolithiasis? | History of prior nephrolithiasis, family history of renal stones, recurrent UTI (especially *Proteus* or *Klebsiella* infections), structural abnormalities (e.g. UPJ obstruction or horseshoe kidney), metabolic disorder (e.g., hypercalciuria or hyperoxaluria), and ketogenic diet. |

## Indications/Contraindications

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|---|---|
| What are common contraindications to any GU intervention? | Uncorrectable coagulopathy or severe anemia, thrombocytopenia (platelets $<50{,}000 \times 10^6$/L), INR >1.5, serious contrast allergy (e.g., anaphylaxis). |
| What are common indications for renal biopsy? | Histologic diagnosis for rising creatinine and worsening renal function, monitoring disease progression (e.g., lupus nephritis), and assessing for renal allograft rejection. |
| What are common indications for PCN placement? | Relief of urinary obstruction, drainage of complications of pyelonephritis, urinary diversion for urinary leaks, antegrade pyelogram, percutaneous calyceal access for nephrolithotomy. |
| What are common indications for dilation/stenting of ureteral strictures? | Congenital ureteral stenosis, fibrous bands, postoperative stricture (e.g., post-transplant), and anomalous ureteral insertions. |
| What are relative contraindications for dilation/stenting of ureteral strictures? | Strictures longer than 2 cm, active infection, significant segmental ureteral ischemia, recent surgery (e.g., ureteral implantation or renal transplant in the last 30 days). |

## Relevant Anatomy

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|---|---|
| The kidneys are located in the retroperitoneum at what vertebral level? | T12 to L2/L3. Due to the adjacent liver, the right kidney is typically slightly more inferior compared to the left. |
| What is the name of the fascia that defines the perirenal space? | Gerota's fascia. |

| | |
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| In standard renal arterial anatomy, each kidney is perfused by one renal artery. What percentage of the population has multiple renal arteries? | 30%. Accessory arteries may arise from the aorta or iliac arteries. |
| What is Brodel's line? | A relatively avascular plane located along the posterolateral kidney that lies between the anterior and posterior segmental branches of the renal artery. |

## Relevant Materials

| | |
|---|---|
| What imaging modality is preferred for renal biopsy in pediatric patients? | Ultrasound. CT may be used for targeted lesions not well seen on ultrasound, difficult anatomy (e.g. severe scoliosis or ectopic kidneys), and morbidly obese patients. |
| What biopsy needle (size and type) should be used during renal biopsy? | 16 G–18 G semiautomated core needle system. |
| | 18 G may be preferred in infants, children <10 kg, or patients with higher bleeding risk. |
| What imaging modality is most often used for guidance during PCN placement? | Ultrasound for percutaneous access into a calyx and fluoroscopy for placement of the catheter into the renal pelvis or bladder. |
| What size access needle should be used for PCN placement? | 8–22 G needle. |

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| What guidewire (size and type) should be used to advance the PCN drainage catheter? | Begin with 0.018″ wire advanced through the needle into the renal pelvis and dilate the percutaneous tract until the wire can be exchanged for a 0.035″ relatively stiff guidewire (e.g., Amplatz or Rosen). |
| What PCN drainage catheter (size and type) should be used? | 5–6 Fr locking (e.g., Cope loop) Pigtail catheter.<br><br>Larger catheters (e.g., 8–10 F) can be used in older children >20 kg. |
| What imaging modality is most often used to guide dilation/stenting of ureteral strictures? | Fluoroscopy. |
| What guidewire (size and type) should be used to traverse a ureteral stricture? | For particularly tight strictures, an 0.018″ guidewire may be necessary to cross the stenosis. Otherwise, a 0.035″ hydrophilic guidewire is used. |
| What type of catheter may be used to traverse a ureteral stricture? | Angle-tipped hydrophilic catheter, usually 4 Fr. |
| What size angioplasty balloon should be used? | Balloon diameter should be 1–2 mm wider than the normal-appearing ureter. Measurements of the ureter should be obtained from the nephrostogram. Generally, 6–10 mm diameter balloons can be used for UPJ and UVJ strictures, whereas 4–6 mm diameter balloons are used for ureteral strictures. |
| Name two types of catheters that can be used for ureteral stenting. | Double-J catheter (i.e., nephroureteric stent; internal drainage) or percutaneous nephroureteral catheter (i.e., PCNU or internal-external drainage). |

## General Step by Step

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|---|---|
| What is ideal patient positioning for renal biopsy? | Prone or lateral decubitus with patient facing away from the operator. A wedge can be placed under the patient, above the iliac crest, to open the window between the iliac crest and the 12th rib. |
| What anatomic plane can be used to determine renal biopsy skin entry site? | Mid-scapular line. |
| Where is the ideal site to biopsy the kidney? | Inferior pole (reduces risk of pneumothorax) along the superficial cortex, where glomeruli are most dense. |
| What is ideal patient positioning for PCN placement? | Prone or oblique facing away from the operator. |
| What is the route of an ideal nephrostomy track? | Traversing the renal parenchyma and entering a posterior, middle, or inferior calyx, |
| What is the disadvantage of a direct puncture of the renal pelvis? | Limited surrounding renal parenchyma to provide tamponade against bleeding or urine leak as well as greater risk to hilar structures (e.g., renal vein/artery). |
| What is the "double stick" method? | A small-caliber needle (e.g., 22 G) is used to access the collecting system and inject a small amount of contrast to opacify the system. An ideal calyx is then targeted with a second needle under fluoroscopy. |
| Following the return of urine though the access needle, what is the next step? | Advance the guidewire through the needle, ideally into the ureter. |

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| What is the preferred final position of the nephrostomy catheter? | Advance until the Cope loop can be fully formed inside the renal pelvis. |
| What is the route of an ideal percutaneous nephrostomy track for dilation/stenting of ureteral strictures? | Interpolar or upper pole calyceal access reduces entry angle and offers more direct trajectory for accessing the UPJ and ureter. |
| After traversing the stricture with a hydrophilic wire and coiling it in the bladder, what is the next step? | Exchange for a stiff guidewire over which the angioplasty balloon can be passed. |
| If the stricture persists following multiple balloon dilations, what can be considered? | Dilation of the stricture using a cutting balloon. |
| How can the length of an internal ureteral stent be estimated? | Length (cm) = Patient age (yrs) + 10.<br><br>Alternatively, the "bent wire method" may be used. |

## Complications

| | |
|---|---|
| What are some minor complications of renal biopsy? | Asymptomatic perinephric hematoma (85%) and transient gross hematuria (6–8%). |
| What are some major complications of renal biopsy? | Hemorrhage requiring transfusion (1–3%), hematoma causing renal compression or Page kidney, vascular injury (arteriovenous fistula or pseudoaneurysm formation), or pneumothorax. |

| | |
|---|---|
| What are some minor complications of PCN placement? | Asymptomatic perinephric hematoma and transient gross hematuria. |
| What are some major complications of PCN placement? | Hemorrhage requiring transfusion, sepsis, and urine leak. |
| Following PCN placement, the patient develops rigors. What is the best course of management? | Demerol (0.8–1 mg/kg up to 50 mg IV). |
| | In addition, hemodynamic monitoring, IV fluid bolus, broad-spectrum antibiotics (e.g., Levofloxacin or Ampicillin/Sulbactam) should be considered. |
| What are some acute complications of ureteral stricture dilation/ stenting? | Acute post-procedure obstruction (especially with balloon dilation without stent placement), transient hematuria, ureteral rupture and urine leak, and UTI/Urosepsis. |
| What are some delayed complications of ureteral stricture dilation/ stenting? | Stent migration, recurrence, and need for additional intervention, UTI/ Urosepsis. |

## Common Questions

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|---|---|
| How long following a renal biopsy should the patient be monitored? | Although observation time varies by institution, 98% of complications manifest within 24 hours. |
| How often should PCNs and stents be replaced? | Approximately every 2–3 months to prevent occlusion from calcification/debris and/or infection. |

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| Name two common reasons why a PCN or stent may stop draining. | Dislodgement (check suture site) or occlusion (flush with 5–10 mL of saline). |
| What is Nutcracker syndrome? How do affected patients often present? | Compression of the left renal vein between the SMA and the abdominal aorta. This results in venous hypertension which, if severe enough, can cause gross hematuria due to rupture of thin-walled varices into the renal collecting system. Patients may also present with a varicocele. |

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# Part XI
# Other and New Procedures

# Chapter 59
# Tubes and Biopsies

**Oleksandra Kutsenko and Mohammed Jawed**

## Biopsies

### *Clinical Considerations*

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|---|---|
| What are the indications for percutaneous biopsy? | Biopsies can help to diagnose malignancy, guide staging, estimate prognosis, provide molecular analysis, identify susceptibility to targeted treatments, determine possible familial risk, and evaluate response to treatment. Liquid biopsies can detect circulating tumor cells or tumor-associated proteins in the blood or fluid collections. In addition, biopsies can differentiate benign lesions such as tumors, cysts, infection, or inflammation. Finally, sampling of an infected collection can assess cellular and microbiologic content as well as determine bacterial antibiotic sensitivity to guide the treatment. |

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| What is the significance of the NCI-MATCH Precision Medicine Cancer Trial? | The National Cancer Institute-Molecular Analysis for Therapy Choice (NCI-MATCH) trial is the largest precision medicine cancer trial to date based on the number of patients, treatment arms, and types of cancer being studied in a single clinical trial. It enrolls patients at nearly 1100 cancer centers and seeks to determine whether matching certain drugs or drug combinations in adults whose tumors have specific gene abnormalities will effectively treat their cancer, regardless of their cancer type. Treatment focuses on molecular abnormalities instead of the anatomic organ site of cancer. The trial is inherently dependent on obtaining a high-quality biopsy sample for molecular and genetic analyses. |
| What are the contraindications to performing percutaneous biopsy? | No absolute contraindications. Relative contraindications to percutaneous biopsy include uncorrectable coagulopathy, large body habitus, unfavorable location of the biopsy target, severely compromised cardiopulmonary function or hemodynamic instability, the patient's inability to cooperate, or the patient's refusal of the procedure. |
| Who has an increased risk of bleeding? | Patients with congenital bleeding diatheses, disseminated intravascular coagulation, sepsis, and renal dysfunction have an increased risk of periprocedural bleeding. In addition, a bleeding episode within 3 months of a procedure, prior bleeding with percutaneous biopsy, platelet abnormality, increased INR, prior bleeding with bridging therapy, mechanical mitral heart valve, and active cancer further increase the risk of post-procedural hemorrhage. |

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| What is the HAS-BLED score? | HAS-BLED score is often used to guide clinical practice in recognizing potential factors that may increase patient-specific bleeding risk. Assessment criteria include hypertension, abnormal renal or liver function, prior stroke, history of major bleeding or predisposition to bleeding, labile INR, age >65 years old, concomitant use of antiplatelet agent or NSAID, and history of alcohol or drug use. A score of >3 predicts a bleeding event. |
| What are the recommended laboratory test thresholds for percutaneous biopsies? | *Low bleeding risk* (procedures including superficial biopsy of a palpable lesion, lymph node, soft tissue, breast, thyroid, superficial bone as well as transjugular liver biopsy): INR <2.0–3.0 and platelets >20,000 per μL.<br><br>*High bleeding risk* (procedures including deep non-organ biopsies and all solid organ biopsies): INR <1.5 and platelets >50,000 per μL.<br><br>*Biopsies in patients with chronic liver disease*: INR <2.5, platelets >30,000 per μL, fibrinogen >100 mg/dL |
| What level of sedation is required for percutaneous biopsy? | Many of the percutaneous biopsies are performed with local anesthesia using 1% or 2% lidocaine. For more complex biopsies that may require significant needle manipulation and/or biopsies of the deeper structures, moderate sedation or general anesthesia can be considered. |
| Does the patient need to be NPO? | Yes, for sedation and general endotracheal anesthesia (GETA). Though it can be variable per institution, the patient must withhold solid food for 6 hours and clear liquids and medications for 3 hours prior to the procedure. Some advocate NPO for 8 hours for general anesthesia. |

## *Technical Considerations*

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| Name the types of image-guided percutaneous biopsies. | 1. Non-targeted organ biopsy—performed to determine a histologic pattern of generalized organ pathology such as hemochromatosis, amyloidosis, hepatic cirrhosis, chronic kidney disease, etc.<br>2. Targeted tissue biopsy—performed to identify histologic and/or genomic pattern of a focal lesion.<br>3. Fluid sampling—performed to determine cytologic and/or microbiologic content of the fluid collection within the physiologic or pathologic space. These may include loculated fluid collections, pleural effusion, ascites, pericardial effusion, etc. |

What imaging modalities can be used to guide a biopsy?

| **Modality** | **Advantages** | **Disadvantages** | **Excellent target** |
|---|---|---|---|
| Ultrasound | Availability<br>No radiation<br>Inexpensive<br>Portable<br>Real-time<br>Fast target localization<br>Multiplanar and allows off-plane angulation | Requires good acoustic window | Any superficial organ or structure: thyroid, lymph node, kidney, etc. |
| Computer tomography (CT) | High spatial and contrast resolution<br>Precision<br>Multiplanar<br>Contrast enhancement | Radiation<br>Expensive<br>Difficult off-plane angulation<br>Time-consuming | Bone lesions, any deep structures, lung. |

| Modality | Advantages | Disadvantages | Excellent target |
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| Fluoroscopy | Availability<br>Inexpensive<br>Real-time | Radiation<br>Interposed structures and blood vessels are not visualized | Bile ducts, ureters, transjugular liver biopsy. |
| Magnetic resonance imaging (MRI) | High sensitivity of lesion detection<br>Multiplanar<br>No radiation<br>Precision | Difficult off-plane angulation<br>Expensive<br>Requires MRI-compatible equipment<br>Limited availability | Breast, prostate. |

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| What are the two most common techniques of percutaneous needle biopsy? | Single stick: Entire biopsy device is inserted and removed for each pass of the sampling.<br><br>Coaxial: Trocar needle is inserted into the target tissue and left in place while smaller gauge needle is coaxially passed through the trocar to take multiple samples. A coaxial needle biopsy is a faster and safer method with a lower rate of complications |
| What needle size should one choose to acquire an adequate sample? | Core needle biopsy is performed for histologic sampling: 18-gauge or larger needle (9–13 gauge for breast tissue genomic testing)<br><br>Fine needle aspiration (FNA) is performed for cytologic sampling: 22- or 25-gauge needle. |

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| What needles are available for an FNA biopsy? | A Chiba needle is commonly used. Alternatively, Franseen, Westcott, Greene, and Spinal needles can be used. |
| What types of devices are available for a core biopsy? | Trocar needle with diamond-tip stylet and Greene are both coaxial needle systems. Biopty and Temno are spring-activated cutting needles. |
| What is the best biopsy target in the lesion? | The highest biopsy yield is at the periphery of the lesion avoiding necrotic center. In complex cystic and solid or heterogenous lesions sampling of the solid, most aggressive, disorganized component should be obtained. Biopsy of multiple different areas should be attempted, while avoiding paucicellular tissues such as fibrosis/scarring, cystic change, and necrosis. Color Doppler can help to identify areas of living tissue. |
| How to preserve collected samples? | Cell culture medium is used for the sample of cells that are to be grown or subjected to flow cytometry. Formalin can be used for the sample that is to be analyzed structurally. |

What are some of the challenges of the image-guided percutaneous biopsy?

| **Challenge** | **Solution** |
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| Low conspicuity, isodense lesion | Contrast enhancement, dual-modality image fusion (PET/CT, CT/US, or MR/US fusion) |
| Small size, complex path to lesion | Triangulation method, gantry tilt technique, CT fluoroscopy |
| Overlying or intervening structures | Patient repositioning, hydrodissection |
| Motion | Sedation, breath hold |
| Air introduced into target tissue following repeated insertions of the needle | Drip sterile saline into the needle hub each time the inner needle is withdrawn |
| Bowel peristalsis | Administer glucagon |

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| What are the major complications associated with image-guided percutaneous biopsy? | 1. Bleeding: 5–10% with large needle, 3% with small needle, and 0.1–2.0% with fine needle<br>2. Pneumothorax: 5% with lung biopsies and 0.5% with non-lung biopsies<br>3. Infection: 1% for sterile biopsies and 2.5–3% for nonsterile prostate biopsy<br>4. Injury to a target organ: <2%<br>5. Peritonitis: 1.5%<br>6. Hemoptysis: 0.5% with lung biopsies |
| What techniques could be used to mitigate the potential risk of bleeding? | Using a coaxial approach and ablating the tract with <2 mL of absolute ethanol induces coagulation necrosis in the tract that not only stops the bleeding but also mitigates the very small risk of tumor seeding. |

## *Organ-Specific Considerations*

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| What is the safest approach to perform a liver biopsy? | Left hepatic lobe is most accessible via epigastric subxiphoid approach that allows avoiding major vessels and pleura. Right hepatic lobe is well accessible via subcostal or low intercoastal approach. Diaphragm should be avoided. Transparenchymal route with at least 2–3 cm of normal hepatic tissue peripheral to the lesion is safe as it allows the normal liver to tamponade potential hemorrhage. In patients with uncorrectable coagulopathy or massive ascites requiring a non-targeted sampling a transjugular or transfemoral transcaval liver biopsy can be alternatively performed. |

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| Describe the technique of transjugular liver biopsy. | The access is obtained via the right internal jugular vein, and a needle advanced through superior vena cava, right atrium, inferior vena cava (IVC), and into the hepatic veins. Biopsy is performed through the right or middle hepatic vein. |
| What patients can benefit from a transfemoral transcaval liver biopsy approach? | Patients with difficult hepatic vein cannulation due to contractures as seen in cirrhosis or Budd-Chiari syndrome, patients with increased risk for arrhythmias on whom crossing right heart is dangerous, thrombosed or scarred internal jugular vein as seen in head and neck cancer patients after radiation therapy, or when single IR operator is available for the procedure (a second operator is needed for transjugular biopsy to maintain the position of the cannula in the hepatic vein while the biopsy needle is manipulated). In these scenarios, hepatic tissue can be obtained directly through the intrahepatic inferior vena cava via common femoral venous access. |
| What adjunctive techniques can be used in the biopsy of the hepatic dome lesion? | The percutaneous biopsy of the hepatic dome lesions is challenging due to difficult access and increased potential for complications associated with diaphragmatic, lung, or pleural injury. Adjunctive techniques such as hydrodissection, artificial pleural effusion or pneumothorax, carbon dioxide insufflation, and angiographic balloon interposition can minimize the risks of the procedure. |
| What is Kehr's sign? | Kehr's sign is an acute prolonged (>5 min) shoulder pain due to the presence of blood in the peritoneal cavity when a person is lying down, and the legs are elevated. It suggests post-procedural bleeding and requires ultrasound re-evaluation for blood in the Morrison's pouch. |

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| What is carcinoid crisis? | The biopsy of carcinoid metastasis should be avoided as it may cause a massive release of vasoactive substances and cause carcinoid crisis and potential death. A patient may experience severe flushing, nausea, faintness, generalized seizure activity, profound hypotension, and cardiopulmonary arrest. |
| What is the clinical significance of diagnostic aspiration of pleural effusion? | Cytologic evaluation of pleural fluid provides important clinical staging information. The presence of a malignant effusion upstages the disease to stage IV for most cancers. |
| What are the safety considerations during the percutaneous lung biopsy? | Performing a single pleural puncture with a coaxial needle system decreases the risk for pneumothorax. Prone position is preferred to minimize chest wall motion. Aim to bypass interlobar fissures, bullae, vessels >5 mm, and bone. Enter the lung at 90° angle to pleural surface. The post-procedure patient should be placed on the ipsilateral to biopsy side. |
| When is a chest tube required post lung biopsy? | Pneumothorax is a common complication of percutaneous lung biopsy. A 8–10-Fr pigtail chest tube should be placed if the patient is symptomatic or the pneumothorax continues to enlarge on serial radiographs. Aspiration of the air with a syringe can be attempted. |

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| What is the significance of BATTLE clinical trial? | The BATTLE study is the first completed prospective, adaptively randomized study in heavily pretreated non-small cell lung cancer (NSCLC) patients that mandated tumor profiling with real-time biopsies. The trial realizes personalized lung cancer therapy by integrating real-time molecular laboratory findings in delineating specific patient populations for individualized treatment. The results of BATTLE-1 trial demonstrated that image-guided 20-gauge percutaneous transthoracic core-needle biopsy is safe and provides adequate tissue for the analysis of multiple biomarkers in a majority of patients. Metastatic lesions are more likely to yield diagnostic tissue as compared with primary tumors. |
| What are the indications to perform a renal mass biopsy? | Historically, all solid renal masses that lack macroscopic fat required surgical resection due to the risk of upstaging the lesion and seeding the track. However, in recent years, several advances in imaging, procedural, and cytologic techniques have allowed percutaneous biopsy to play a larger role in the evaluation of renal masses to avoid unnecessary surgical or ablative therapies. Renal mass biopsy should be considered when a mass is suspected to be hematologic, metastatic, inflammatory, or infectious. After a full imaging work-up a percutaneous renal mass biopsy should be performed in patients with known extrarenal primary cancer, unresectable renal cancer, renal mass that may be caused by infection, patients with comorbidities that increase the risk of a surgical procedure, patients with a small ($\leq$3 cm), hyperattenuating, homogeneously enhancing renal mass, patients with a renal mass for which percutaneous ablation is considered, and indeterminate cystic renal mass. |

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| What approach should be utilized for non-focal kidney biopsy? | Non-targeted renal biopsy is performed as a workup for renal failure. Lateral (lesion side down) posterior approach is preferred as it stabilizes the kidney from respiratory motion and bowel interposition. Percutaneous biopsy is performed using a 14- to 18-gauge cutting needle. Samples should be obtained from the lower pole cortex where the glomeruli yield is the highest. This approach also minimizes complications by avoiding the renal hilum. In patients with uncorrectable coagulopathy, a transjugular renal biopsy can be alternatively performed. |
| What is Page kidney? | Page kidney should be suspected in any patients who present with hypertension, flank pain, and reduced renal function that started after a percutaneous renal biopsy. Page kidney refers to systemic hypertension secondary to extrinsic compression of the kidney by a subcapsular collection (e.g., hematoma, seroma, or urinoma). Compression of the kidney results in compression of the intrarenal vessels, which leads to decreased blood flow to the renal parenchymal tissue and induction of renin secretion. Renin-angiotensin system activation results in hypertension. |
| What approach is used to biopsy an adrenal lesion? | A posterior approach in patients positioned in the ipsilateral decubitus position is most commonly used. Placing the patient in a decubitus position restricts diaphragmatic motion and decreases lung inflation reducing the risk of pneumothorax. Needle transgression of the diaphragm, kidney, aorta, and splenic vessels should be avoided. Alternatively, right (lateral) or left (anterior) transhepatic approaches can be used. |

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| What structures should be avoided during the transgluteal presacral/pelvic mass biopsy? | Needle path during the transgluteal percutaneous biopsy should lie posteromedial close to the sacrum to avoid the sciatic nerve anterolaterally, and below the piriformis muscle to avoid the gluteal vessels. |
| Is the splenic biopsy technique different from a liver biopsy? | Spleen biopsy should be performed traversing as little parenchyma as possible, while hepatic lesion biopsy should be performed traversing generous amount of parenchyma to minimize the bleeding risk. |

# Drainage Tubes

## *Clinical Considerations*

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| What is the difference between percutaneous drainage and aspiration? | Percutaneous drainage is defined as the placement of a catheter to provide continuous transorificial (transrectal, transvaginal, peroral) or transcutaneous drainage of a fluid collection. Percutaneous aspiration is an evacuation of a fluid collection with the immediate removal of the needle or catheter after the aspiration. |
| What types of collections are amenable to percutaneous drainage or aspiration? | Benign cystic disease; infectious causes from bacterial, fungal, mycobacterial, or parasitic organisms; postsurgical seromas or lymphoceles; perforation or rupture and leakage from hollow viscus or conduits; and collections formed secondary to inflammatory states or diseases. |

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| What are the indications for percutaneous drainage or aspiration? | Not all pathologic collections require drainage. The percutaneous aspiration or drainage should be performed if there is a suspicion that the fluid is infected, the collection communicates with an abnormal fistula, the patient is symptomatic, or if the patient needs an adjunctive procedure to facilitate the improved outcome of a subsequent intervention (paracentesis before liver intervention, access to a cyst for drainage and sclerosis). |
| What are the contraindications for percutaneous drainage? | No absolute contraindications. Relative contraindications include uncorrectable coagulopathy, severely compromised cardiopulmonary function or hemodynamic instability, unfavorable location with lack of safe pathway, the patient's inability to cooperate, or the patient's refusal of the procedure. |
| What are the recommended laboratory test thresholds for percutaneous drainage? | Percutaneous drainage has a moderate risk of bleeding. Recommended INR >1.5, platelets >50,000 per μL. |
| Is antibiotic therapy indicated prior to percutaneous drainage? | Yes. Initiation of antibiotic therapy is recommended and should be continued after aspiration and drainage as manipulation within the abscess with a wire or needle poses the risk of rupturing the cavity and spilling its contents into the surrounding space. This generally does not affect cultures. Abdominal abscesses are frequently polymicrobial, and broad-spectrum antibiotic agents, such as meropenem, imipenem/cilastatin, doripenem, piperacillin/tazobactam, or a combination of metronidazole with ciprofloxacin, levofloxacin, ceftazidime, cefepime, or ampicillin/sulbactam are warranted. For pleural abscesses, antibiotic regimens such as, piperacillin/tazobactam or amoxicillin/clavulanic acid are suggested. |

## *Technical Considerations*

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| Name two techniques of percutaneous collection drainage. | The trocar technique can be used for the drainage of large superficial collections. The access is obtained with a 20-gauge needle, the catheter is loaded on a trocar delivery system and advanced in tandem to the needle, the inner stylet is removed and fluid is aspirated through the metal stiffener, then the catheter is advanced and locked to coil within the collection.<br><br>Modified Seldinger technique is preferred in difficult drainages of small, remote, deep collections with limited access. The access is obtained with a thin needle (20-gauge Chiba or Ring needle), the tract is serially dilated using coaxial exchanges of guidewires and dilators, and a large catheter is inserted within the collection. |
| What size drainage catheter should be used? | The thicker the fluid, the bigger the drainage catheter that should be placed;<br><br>Clear fluid: 6–8-Fr<br><br>Thin pus: 8–10-Fr<br><br>Thick pus: 10–12-Fr<br><br>Collections with debris: 12+ French |
| What amount of fluid should be used to irrigate the collection? | Small volumes of saline (5–20 mL) should be used and should not exceed the volume of the cavity as overdistention may cause bacteremia. |
| What is an abscessogram? | An abscessogram is a fluoroscopically guided contrast injection in the drainage catheter with the goal to document resolution of a fluid collection, identify fistulae, or troubleshoot malfunctioning catheters. |

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| How should drainage catheters be maintained? | Draining catheters are typically anchored to the skin with nonabsorbable suture or adhesive device. Catheters should be flushed every day with at least 5–10 mL normal saline solution to maintain patency. |
| When should drainage catheters be removed? | Sinogram, CT, or US imaging demonstrating diminished collection size and absence of fistula; the patient exhibits clinical improvement; and/or when the catheter drains <10 mL for several days |
| What adjunctive techniques can be used in the management of persistent collections? | Intracavitary installation of fibrinolytic agents (4–6 mL of tissue plasminogen activator diluted in 50 mL normal saline), upsizing to a larger catheter, or using a catheter with more side holes (e.g., Cope-type loop biliary catheter) |
| What major complications are associated with percutaneous drainage procedures? | Hemorrhage, hemo−/pneumothorax, bowel or pleural transgression requiring intervention, enteric fistula, peritonitis, superinfection, bacteremia, and septic shock |

## *Organ-Specific Considerations*

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| What is the significance of percutaneous abscess drainage in patients with Crohn's disease? | Percutaneous drainage allows delay of surgery until inflammation resolves, nutritional status is optimized, and corticosteroids are discontinued. This results in a decreased extent of bowel resection and possibly a one-stage surgical intervention. |
| What approaches can be used for pelvic collection drainage? | Transabdominal: It usually requires a longer path to reach the collection. Epigastric arteries should be evaluated with Doppler to prevent vascular injury and bleeding. |

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| | Transgluteal: The catheter should be inserted through the sacrospinous ligament as close as possible to sacrococcygeal margin to avoid sciatic nerve injury and inferior to the piriformis muscle to spare the gluteal arteries.<br><br>Transvaginal: Often provides shortest and safest route to drain infected gynecologic fluid collections, recurrent endometriotic cysts, symptomatic hemorrhagic cysts, or postoperative collections. This route should be favored in pregnant patients.<br><br>Transrectal: The shortest, safest, and least painful route to drain pre-sacral collection. It requires cleansing enema prior to the procedure. |
| What anatomical structures should be avoided during liver collection drainage? | Large vessels, dilated bile ducts, gallbladder, and pleura. |
| What therapeutic approach should be employed in the management of infected necrotizing pancreatitis? | Infected necrotizing pancreatitis has an overwhelming mortality rate of 20–40%, and always requires an intervention. The optimal interventional strategy includes image-guided percutaneous (retroperitoneal) catheter drainage, followed, if necessary, by endoscopic or surgical necrosectomy. A considerable number of patients can be successfully treated with minimally invasive percutaneous drainage alone, sparing the surgery. Some patients may require a step-up approach that involves percutaneous drainage of the pancreatic abscess collection followed by video-assisted retroperitoneal debridement along the route of the retroperitoneal drainage catheter. |

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| What is the most common complication of infected necrotizing pancreatitis? | The formation of a pancreatic fistula is the most common complication and should be suspected if the drainage output persists or increases. Pancreatic cutaneous fistula can be confirmed with amylase test. Adjunctive octreotide therapy may be helpful to close the fistula. |
| Name relevant anatomic structures for safe pleural drainage. | Intercostal access should be obtained above the rib to avoid the neurovascular bundle. Typically, sixth or seventh intercostal space in the midaxillary line is preferred. Paravertebral approach is less favored as the posterior intercostal vessels course off the ribs and are more prone to injury. |
| Should all parapneumonic effusions be drained? | No. Free-flowing small–to-moderate pleural effusions do not require drainage. Parapneumonic effusions category 3 (large >50% of hemithorax free-flowing effusion, loculated effusion, effusions causing thickened parietal pleura, pleural effusions with pH <7.2, or pleural glucose <60 mg/dL) and category 4 (frank pus in pleural space) require drainage. |
| What is trapped lung syndrome? | The inability of the lung to re-expand after pleural effusion drainage due to thick fibrous or malignant tissue encasing the visceral pleura. This is a relevant contraindication to pleural drainage as it is rarely successful. |
| Does lung abscess require percutaneous drainage? | Percutaneous drainage of lung abscess may cause bronchopleural fistula and should be avoided. Drainage is, however, recommended in patients with persistent sepsis (5–7 days after the initiation of antibiotic therapy), abscess size >4 cm with an air fluid level, increased abscess size while on antibiotic therapy, and in children <7 years old. |

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# Chapter 60
# Bariatric Embolization

**Clifford R. Weiss and Godwin Abiola**

## Evaluating the Patient

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| How is obesity usually classified? | Obesity is normally defined by calculating a patient's body mass index (BMI), which is mass (kg)/height$^2$(m$^2$). |

| BMI | Classification |
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| 18.5–25 | Normal |
| 25–30 | Overweight |
| 30–35 | Moderately obese |
| 35–40 | Severely obese |
| 40–45 | Very severely obese |
| 40+ | Morbidly obese |

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| What measures can be used to monitor obesity? | he most common measure of obesity is BMI. Obesity can also be measured through waist circumference. A waist circumference ≥102 cm for men and ≥88 cm for women is considered elevated. Formal assessment of body fat percentage can also provide useful information. |
| What are some causes of obesity to consider in a patient? | Often, obesity can be attributed to behavioral factors such as a sedentary lifestyle and high-calorie diet. Other potential causes for weight gain may include hypothyroidism, Cushing's syndrome, polycystic ovary syndrome, genetic disorders, or medications. |
| What are some of the risks and comorbidities associated with obesity? | Patients should be evaluated for metabolic syndromes, coronary artery disease and cardiovascular health, diabetes, hypertension, sleep apnea, osteoarthritis, dyslipidemia, non-acholic fatty liver disease, and gastrointestinal disorders. |
| How is obesity typically managed? | Depending on the severity of obesity and the capabilities of the patient, different therapies may be recommended. At a minimum, lifestyle changes promoting a healthy diet and regular exercise are typically recommended. Other therapies include pharmacological agents, such as orlistat, phentermine, lorcaserin, and liraglutide, as well as various bariatric surgeries and endoscopic interventions. |

## Indications/Contraindications

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| Who is eligible for bariatric embolization? | As of now, this procedure should remain in the purview of prospective IRB-approved investigations. In the United States, this procedure has been tested in severely obese patients (BMI ≥ 40) weighing less than 400 lbs., and who are less than 65 years of age and otherwise healthy. In non-US studies, patients with BMIs ≥ 30 have been included. Patients should demonstrate a history of failed attempts at weight loss through lifestyle modifications. Patients should express that they are unwilling to have bariatric surgery in the future, because the safety of these surgeries after embolization is not known. Patients should also demonstrate an understanding that this is an experimental treatment with unknown efficacy. |
| Is bariatric embolization standalone therapy? | Currently, bariatric embolization is not considered a standalone therapy. The treatment, as part of a research protocol, should be combined with lifestyle changes in diet and exercise that would also promote a healthy weight loss. |
| When would bariatric embolization be used over bariatric surgeries? | Bariatric embolization is being explored to be an additional option for weight loss in patients who would not qualify for bariatric surgery. Bariatric surgery has a long history, with a known clinical efficacy that is much greater than early studies of bariatric embolization. Currently, as a standalone procedure, bariatric embolization is not viewed as a procedure that will replace bariatric surgery. More studies need to be performed to solidify the role of this therapy in the context of currently performed weight loss interventions. |

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| What are absolute contraindications for bariatric embolization? | Any condition that might put a patient at risk for gastric perforation such as active ulcers, gastric malignancy, a history of gastric surgery or radiation or connective tissue disorders. Until proven that bariatric embolization does not preclude future gastric bypass or sleeve gastrectomy, patients who are willing to undergo these procedures should be encouraged to consult a licensed bariatric surgeon. |

## Relevant Anatomy

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| What are the main branches of the celiac artery? | The main branches of the celiac artery, or trunk, are the common hepatic artery, left gastric artery, and splenic artery. |
| What are common variants to the celiac axis and major adjacent branches of the aorta? | The most common appearance of the celiac axis is bifurcation of the celiac axis into a hepatosplenic trunk and left gastric artery (50–76%) or classic trifurcation of the main arteries (10–19%). The left gastric artery may sometimes come directly off of the aorta (4.4%), or share a common origin with the superior mesenteric artery (2.6%). In 10%, more branches may originate directly from the celiac axis, including the pancreatic artery, gastroduodenal artery, and right and left hepatic arteries. |
| What hormones are involved in the promotion of satiety? | The main hormones promoting satiety are GLP-1, PYY, CCK, and leptin. |

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| What hormones are involved in the stimulation of appetite? | The main hormone-stimulating appetite is ghrelin. |
| Where are appetite-regulating hormones produced in the body? | GLP-1 and PYY are produced by L cells within the ileum and colon. CCK is produced by I cells within the small bowel. Leptin is produced by adipocytes in proportion to the number of adipocytes. Ghrelin is primarily produced by X/A cells in the gastric fundus, but also in the duodenum and pituitary gland. |
| What vessels supply the fundus of the stomach? | The gastric fundus is primarily supplied by the left gastric artery and gastroepiploic artery (a terminus of the gastroduodenal artery). Sometimes, the right gastric artery or the short gastric arteries (off of the splenic artery) can contribute significantly to the fundus. |

## Relevant Materials

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| What catheters are used during a bariatric embolization procedure? | A catheter allowing easy entry in the celiac access, such as a SOS selective, should initially be used if using a femoral approach. If using a radial approach, the Jacky, Sarah, or FishHook may be used. A high-flow microcatheter should then be used to subselect individual vessels. |
| What embolic agent is used during bariatric embolization? | Several embolic agents of different material and sizes have been used in clinical trials to varying degrees of success. In general, the most widely used agents for this procedure have been of the particle agents such as polyvinyl alcohol (PVA) or tris-acryl gelatin microspheres. Sizes used in clinical trials have ranged from 300–700 μm. Smaller embolics have been avoided in clinical trials as they may run the risk of gastric perforations. |

## General Step by Step

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| What are the preferred access sites? | The procedure can be performed by accessing the femoral artery or accessing the radial artery. Although there is not a preferred site, per se, radial access may be preferred when treating this patient population. |
| How is it determined which vessels are feeding the fundus of the stomach, the target of embolization? | Pre-procedurally, CTA has been performed. This both assists in eliminating unsafe anatomic variants and provides a clear roadmap before the procedure. After gaining access, angiogram of the celiac axis is typically performed. Contrast injection while performing a cone beam CT of the abdomen can also help establish the perfusion of the stomach. |
| How do you know enough embolic has been given? What is the general endpoint? | Embolization of the arteries is typically taken to stasis or near stasis. Typically, this entails 4–5 cardiac beats to washout after contrast injection. Time should be allowed for redistribution, and then stasis re-assessed. |
| How are patients cared for directly after the procedure? | Patients may experience epigastric pain and nausea soon after the procedure. IV Tylenol, opioids and anti-nausea, anti-emetic therapy should be used for symptoms. Patients should remain in the hospital overnight for management of pain, nausea, vomiting, and to be observed for complications. In trials, most patients have been discharged after 24 hours, once tolerating a clear liquid diet. Patients should follow up as per standard post-procedural care protocols. Endoscopy should be performed after the procedure to assess for ulceration. Weight management follow-up is essential. |

## Complications

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| What are potential complications to this procedure? | Complications of bariatric embolization are similar to other vascular interventions. These include arterial dissection, nephrotoxicity from contrast use, pseudoaneurysm, hematoma, and nontarget embolization of nearby structures. Potential and severe complications more unique to bariatric embolization include gastric ulceration requiring more than medical management, and even gastric perforation. In studies so far, these severe complications have not occurred.<br><br>Many patients do develop small, superficial ulcers after the procedure, but these are often asymptomatic, and tend to resolve on their own. |
| What is the most lethal complication of bariatric embolization? | As of now, there are no reported mortalities associated with bariatric embolization. |

## Landmark Research

Gunn AJ, Oklu R. A preliminary observation of weight loss following left gastric artery embolization in humans. *J Obes*. 2014;2014:185349. doi:https://doi.org/10.1155/2014/185349.

- First retrospective study comparing weight loss in 19 patients undergoing left gastric artery embolization vs. 28 patients undergoing embolization of other branches of the celiac axis in patients undergoing embolization for upper gastrointestinal bleeding.

- Patients who underwent left gastric artery embolization lost an average of 7.3% of their initial body weight within 3 months post embolization, which was significantly greater than the average of 2% body weight loss observed in patients who underwent embolization of other vessels.
- The difference in weight loss between the two groups was greatest and most significant at 1-month post embolization.

Kipshidze N, Archvadze A, Bertog S, Leon MB, Sievert H. Endovascular Bariatrics: First in Humans Study of Gastric Artery Embolization for Weight Loss. *JACC Cardiovasc Interv*. 2015;8(12):1641-1644. doi:https://doi.org/10.1016/J.JCIN.2015.07.016.

- This is the first prospective study testing the safety and efficacy of left gastric artery embolization in 5 morbidly obese patients.
- All patients reported decreased appetite after the procedure.
- Mean weight loss was 10%, 13%, 16%, 17%, and 17% at 1, 3, 6, 12, and 20–24 months, respectively.
- Serum ghrelin levels dropped by 29%, 36%, and 21% at 1, 3, and 12 months, respectively.

Syed MI, Morar K, Shaikh A, et al. Gastric Artery Embolization Trial for the Lessening of Appetite Nonsurgically (GET LEAN): Six-Month Preliminary Data. *J Vasc Interv Radiol*. 2016;27(10):1502-1508. doi:https://doi.org/10.1016/J.JVIR.2016.07.010.

- Prospective trial testing the safety and efficacy of left gastric artery embolization in 4 morbidly obese patients.
- Mean body weight loss at 6 months post procedure was 8% body weight, or 17.2% excess body weight.

- Serum leptin levels decreased in 3 patients at 6 months.
- One patient included in the trial had diabetes with a hemoglobin A1c level of 7.4%, which improved to a level of 6.3% at 6 months.

Bai Z-B, Qin Y-L, Deng G, Zhao G-F, Zhong B-Y, Teng G-J. Bariatric Embolization of the Left Gastric Arteries for the Treatment of Obesity: 9-Month Data in 5 Patients. *Obes Surg*. October 2017:1-9. doi:https://doi.org/10.1007/s11695-017-2979-9.

- Prospective single center trial in China testing the safety and efficacy of bariatric embolization in 50 patients.
- Initial report of the first 5 patients at 9 months showed a mean weight loss of 8.28%, 10.42%, and 12.9% at 3, 6, and 9 months, respectively.
- Serum ghrelin decreased by 40.83%, 31.94% and 24.82% from baseline at 3, 6, and 9 months.
- Patients included in this trial had a BMI >30, including obese patients, which is different from American trials which typically only include morbidly obese patients (BMI >40).

Weiss CR, Akinwande O, Paudel K, et al. Clinical Safety of Bariatric Arterial Embolization: Preliminary Results of the BEAT Obesity Trial. *Radiology*. 2017;283(2):598-608. doi:https://doi.org/10.1148/radiol.2016160914.

- Prospective trial conducted at two centers testing the safety and efficacy of bariatric embolization in 20 patients.
- Average weight loss was 4.3%, 6.02%, 6.74%, and 5.96%, at 1,3,6, and 12 months respectively.
- Eight of twenty patients developed small asymptotic superficial ulcers, but no adverse events occurred.

## Common Questions

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| How is it different from bariatric surgery? How is it similar? | Bariatric embolization is a minimally invasive procedure having similar goals of weight loss as bariatric surgery. Though the restriction of the volume of food a patient is able to consume is one mechanism by which bariatric surgery accomplishes the goal of weight loss, bariatric surgery also appears to influence weight loss in another way. The metabolic profiles of patients tend to change after bariatric surgery, showing decreases in the level of ghrelin. Bariatric embolization was developed to try to emulate the same changes in metabolism without the need for surgical intervention. Bariatric embolization has so far demonstrated a significantly lower efficacy than in bariatric surgery and should be considered an adjunctive tool, which can be used to augment lifestyle changes. Also, bariatric surgery is an approved procedure and is "standard of care" for weight loss in the patient suffering from severe obesity. Bariatric embolization is experimental. |
| How does bariatric embolization work? | The exact mechanism of bariatric embolization is currently being investigated. The leading theory is that by restricting blood flow to the gastric fundus, X/A cells will die, decreasing the amount of ghrelin produced by the stomach, which accounts for 90% of ghrelin produced by the body. This in turn decreases appetite and leads to weight loss. |

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| What lifestyle changes can be expected after bariatric embolization? | Patients should expect weight loss occurring primarily due to decreased appetite. Many patients report reduced "cravings" for specific foods after the procedure. It is strongly advised that patients are supported to continue to make healthy lifestyle decisions even after the procedure is performed. In studies so far, patients who have lost the most weight and have maintained their weight loss are those who have paired bariatric embolization with diet and exercise. |
| What type of follow-up should patients receive after their procedure? | Patients can follow up on an as-needed basis. An endoscopy is recommended to monitor the development of gastric ulcers after the procedure. It is also recommended that patients follow up with a weight management program to continue maintaining a healthy diet and to enact lifestyle changes. |
| How much weight loss can be expected expect? | Patients can expect to lose the most weight in the first 6 months after the procedure. Weight loss can be as much as 8% of total body weight and 17% of excess body weight. |

## Further Reading

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# Chapter 61
# Interventional Radiology-Operated Endoscopy

**Jacob J. Bundy, Jeffrey Forris Beecham Chick, and Ravi N. Srinivasa**

## Evaluating the Patient

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| What applications exist for endoscopy within interventional radiology? | Biliary endoscopy, genitourinary endoscopy, and gastrointestinal endoscopy. |
| How should IRE be incorporated into an interventional radiologist's practice? | Multidisciplinary discussions should be held between interventional radiology, the referring physician, and relevant medical and surgical subspecialties to ensure agreement on the planned procedure and to review all alternative treatment options. |

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## High Yield History

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| What workup should be initiated on a patient undergoing interventional radiology-operated endoscopy? | Laboratory evaluation should include a basic metabolic panel, complete blood count, and coagulation markers. |
| What is percutaneous choledochoscopy or cholecystoscopy? | These techniques involve the percutaneous transhepatic placement of an endoscope into either the peripheral biliary system (choledochoscopy) or gallbladder (cholecystoscopy) through which forceps, lasers, and stone retrievers may be used to aid in the treatment of many biliary disease processes. |
| What is percutaneous genitourinary endoscopy? | This procedure involves obtaining percutaneous access into the renal collecting system with an endoscope to facilitate the placement of internal-external nephroureteral catheters or internalized ureteral stents, foreign body retrieval, and lithotripsy. |
| What is percutaneous gastrointestinal endoscopy? | This procedure involves accessing the small bowel with an endoscope through a percutaneous gastrostomy to facilitate foreign body retrieval and stenting. Lower gastrointestinal endoscopy involves the placement of a rigid or flexible endoscope transrectally into the distal colon to relieve acute colonic obstruction through stent deployment. |

## Indications/Contraindications

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| When might a patient be considered for an interventional radiology-operated endoscopy intervention? | Poor surgical candidates with disease processes requiring direct visualization or procedures requiring extensive manipulation or increased control to correct abnormalities may be considered for interventional radiology-operated endoscopy. |
| What are the indications for percutaneous choledochoscopy or cholecystoscopy? | These methods are used in the treatment of symptomatic biliary obstructions in patients who are not surgical candidates or those with long-term indwelling tubes. Additionally, patients who have failed endoscopic retrograde cholangiopancreatography and have calculi peripheral to the hilum of the liver may be assisted by percutaneous endoscopic management. |
| What are the primary indications for genitourinary endoscopy? | Genitourinary endoscopy is useful in the treatment of stone disease and obstructive uropathy. In addition, endoscopy may aid in crossing ureteral strictures and retrieving migrated renal arterial embolization coils. |
| What are the primary indications for gastrointestinal endoscopy? | Patients with altered surgical anatomy not amenable to esophagogastroduodenoscopy who require gastric foreign body retrieval or placement of colonic stents may benefit from gastrointestinal endoscopy. |
| What are the contraindications to percutaneous interventional radiology-operated endoscopy? | Interventional radiology-operated endoscopy is contraindicated when the international normalized ratio is greater than 1.5 and the platelet count is less than 50,000/μL. |

## Relevant Anatomy

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| What forms of altered anatomy lend themselves toward interventional radiology-operated endoscopy within the biliary system? | Patients with duodenal diverticula, prior biliary reconstructive surgeries such as Billroth-II or Roux-en-Y gastric bypass, or those who have peripheral intraductal stones beyond the reach of endoscopic retrograde cholangiopancreatography. |
| What is preferred angle of access into the gallbladder for cholecystoscopy? | The gallbladder should be accessed along the long-axis to allow a more ergonomic approach for stone sweeping and extraction. |
| Where should a drain be placed following biliary endoscopic interventions? | A transcystic internal-external drainage catheter should be placed and if cholecystoscopy is performed, a cholecystostomy drain should also be placed. |
| Where should the kidney be ideally accessed during genitourinary endoscopy? | Generally, the upper pole of the kidney is the preferred location for IRE access as it facilitates the progressive advancement of the scope along the axis of the kidney with increased visualization of the collecting system without additional torque or angulation required. A lower pole posterior approach is usually utilized for simple urinary drainage. A posterior calyx of the upper or middle collecting system offers the easiest access to the ureteropelvic junction for potential ureteral interventions. |

## Relevant Materials

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| What setup is required prior to initiating interventional radiology-operated endoscopy? | Generally, these procedures are performed under general anesthesia given the concerns of electrolyte disturbances and temperature fluctuation related to the infusion of fluids through the endoscopes. Also, an orogastric and rectal tube should be placed for prolonged procedures to manage fluid shifts during the procedure. |
| What forms of endoscopes may be used during interventional radiology-operated endoscopy? | The available endoscopes include: a 7-French flexible reusable (Storz; Tuttlingen, Germany), 9.5-French flexible disposable (Boston Scientific; Marlborough, MA), 9-French flexible reusable (Olympus America; Center Valley, PA), 16.5-French flexible reusable (Olympus America), and 22.5-French rigid reusable endoscope (Olympus America). |
| What tools may be used to facilitate cholelithiasis or nephrolithiasis fragmentation during percutaneous endoscopy? | Fragmentation or stone removal is facilitated by using electrohydraulic lithotripsy devices, mechanical nitinol stone retrieval baskets, sonographic lithotripsy devices, or percutaneous thrombectomy devices. |

## General Step by Step

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| How is initial access gained for an interventional radiology-operated endoscopy procedure? | Depending on the clinical scenario, the standard techniques used for cholangiography, cholecystostomy, nephrostomy, and gastrostomy are performed in the same session as endoscopy or at least 4–6 weeks before endoscopy to allow time for tract maturation. |
| How is access maintained during interventional radiology-operated endoscopy? | Generally two Amplatz Super Stiff Guidewires (Boston Scientific) are inserted, one of which serves as a safety wire to maintain access at all times during endoscopy. |
| Following tract dilation, how is excess fluid that is continuous instilled through the endoscope to maintain clear visualization expelled? | A peel-away sheath large enough to accommodate the chosen endoscope and the adjacent wire is inserted over one of the guidewires and allows for efflux of excess fluid during endoscopy. |

## Complications

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| What further precautions should be taken prior to interventional radiology-operated endoscopy to ensure safety? | Electrolyte disturbances should be corrected as these may lead to dangerous fluid shifts or arrhythmias during endoscopy. |
| What are some of the general risks involved with interventional radiology-operated endoscopy? | Exacerbation of congestive heart failure due to saline irrigation during the procedures, hemorrhage, infection related to seeding through the access tract, and need for repeat intervention. |

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| When should genitourinary endoscopy be avoided? | Endoscopy with the genitourinary system should be avoid in patients with active urinary tract infections; once the infection is treated, percutaneous interventions can be reconsidered. |

## Landmark Research

Patel N, Chick JFB, Gemmete JJ, Castle JC, Dasika N, Saad WE, et al. Interventional Radiology-Operated Cholecystoscopy for the Management of Symptomatic Cholelithiasis: Approach, Technical Success, Safety, and Clinical Outcomes. AJR Am J Roentgenol. 2018 May;210(5):1164–71.

- Prospective review of 13 patients with symptomatic cholelithiasis underwent cholecystostomy followed by interventional radiology–operated cholecystoscopy with stone removal.
- Primary technical success was achieved in 11 (85%) patients, and secondary technical success was achieved in 13 (100%) patients. The mean procedure time was 164 minutes with a mean time between cholecystoscopy and cholecystostomy removal of 39 days.

Mauro MA, Koehler RE, Baron TH. Advances in Gastrointestinal Intervention: The Treatment of Gastroduodenal and Colorectal Obstructions with Metallic Stents. Radiology. 2000 Jun.

- Comprehensive review of the literature related to the fluoroscopic and endoscopic placement of metallic stents for the treatment of upper and lower GI obstructions
- Combined fluoroscopic and endoscopic-guided placement of stents within the small and large bowel performed by interventional radiology for either gastric outlet obstruction or inoperable malignant strictures had a clinical success rate of 89% and 90%, respectively.

Srinivasa RN, Chick JFB, Cooper K. Interventional Radiology-Operated Endoscopy as an Adjunct to Image-Guided Interventions. Curr Probl Diagn Radiol. 2019 Mar;48(2):184–188.

- Descriptive and pictorial discussion of the setup, equipment, and potential clinical uses of interventional radiology-operated endoscopy.

## Common Questions

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| How may trainees improve their comfort using endoscopy during interventional radiology procedures? | Three-dimensional endoscopic models are simulation tools that may serve as effective teaching platforms to improve technical skills and increase confidence related to incorporating endoscopy into future practice. |
| How successful is cholecystoscopy in facilitating removal of chronic cholecystomy drains? | Recent evidence indicates that cholecystoscopy used for the management of cholelithiasis may facilitate the removal of cholecystostomy drains in upwards of 100% of patients. |
| When should drains be removed following biliary endoscopic interventions? | The transcystic drain may be removed 2 weeks following the procedure and the remaining cholecystostomy tube is downsized until it may eventually be removed. Cholecystostomy drains may generally be removed within 4–6 weeks following cholecystoscopy. |

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# Chapter 62
# Sphenopalatine Ganglion Nerve Block

**Parth Shah and Avinash Pillutla**

## Evaluating the Patient

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| What tests should be included in the work-up for a patient with chronic headaches? | Neurological imaging should be included in a patient with chronic refractory headaches before presuming any of the discussed benign entities. MR imaging is preferred over CT. |
| What other laboratory tests should be performed? | Basic blood work including CBC and BMP should be performed as clinically indicated. Also, the clinician may consider spine imaging as well as CSF studies in the correct clinical setting. |

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| Which specific MRI sequence is often requested in current practice by the protocoling radiologist for the evaluation of the cranial nerves? | 3D CISS (constructive interference in steady-state), a heavily T2-weighted gradient echo MR sequence in addition to more routine pre- and post-contrast sequences. |
| What are some possible autonomic signs of cluster headaches? | Lacrimation, conjunctival injection, ptosis, miosis, rhinorrhea, and nasal congestion can be a few of the signs both the patient and clinician may notice. |
| What current non-interventional therapies exist for cluster headaches? | 100% oxygen or triptans can be utilized for acute headache management. |

## High Yield History

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| What is a cluster headache? | Classically, it is characterized as sudden bouts of orbital or temporal pain often with possible associated autonomic symptoms. |
| How often do cluster headaches occur? | Interestingly, cluster-type headaches are known to occur daily for weeks to months at a time and then go into remission for similar periods of time or even longer. This episodic form is the most common. |
| What is trigeminal neuralgia? | Characterized as recurrent brief episodes of unilateral "electric shock-like" pains that are relatively abrupt in onset and often cease in a similar fashion. |
| What other entities are included in the differential of a cluster headache? | Other than trigeminal neuralgia, a primary stabbing headache, secondary cluster headache, SUNCT syndrome are all differential considerations. A secondary cluster headache is also possible and must be considered. |

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| What diagnoses can cause secondary chronic headaches? | Vascular pathologies such as large intracranial aneurysms, meningioma, nasopharyngeal carcinoma, metastatic disease, and arteriovenous malformations are possibilities. Thus, relevant questions must be asked to the patient to consider any of these entities which may be part of the patient's past medical and surgical history. |
| What differentiates primary stabbing headache from cluster headaches? | Primary stabbing headaches are sharp jabbing pains that occur predominantly in the V1 distribution of the trigeminal nerve. A key distinguishing feature is that no autonomic symptoms are associated, unlike with cluster headaches. |
| Who is commonly affected by chronic daily headaches? | Approximately 4% of the world population is affected, with women being affected 2–3 times more than men. |
| What encompasses chronic daily headaches? | Chronic daily headaches include subtypes such as cluster headache, migraine-type headache, tension type headaches, and medication overuse-related headaches. |
| Who is affected by cluster headaches? | Cluster headaches have a prevalence of less than 1 percent and have a heavily male predominance. |

## Indications/Contraindications

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| How far back has intervention regarding the sphenopalatine ganglion been considered? | As far back as 1908, Sluder described the technique, utilizing cocaine as the agent at that time. |

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| What are some common indications for this procedure? | This treatment can be considered for a variety of entities resulting in facial pain that is refractory to medical therapy. This includes trigeminal neuralgia, cluster headaches, cancers related to the floor of mouth and tongue resulting in pain, and acute migraines among others. Postherpetic neuralgia patients may also benefit. |
| What medications are key considerations prior to intervention? | Assessing the status of drugs such warfarin and other anticoagulants is essential prior beginning any interventional procedure. The risks of holding medication and performing procedure must be weighed in close coordination with the patient's primary care physician and cardiologist. |
| What is sphenopalatine ganglion lesioning? | This involves either anesthetic or neurolytic intervention on the ganglion. In addition, radiofrequency thermocoagulation and pulse radiofrequency are additional techniques. |
| What are some contraindications to sphenopalatine ganglion lesioning? | 1. Infection<br>2. Coagulopathy including the need for anticoagulation and greater risk than benefit from holding medicine<br>3. Acute head trauma<br>4. Hemodynamic instability |

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| What are some benefits of the intranasal approach? | One benefit is that this approach can be quickly done in many outpatient office settings. Additionally, it is less invasive and while risk of epistaxis is not completely mitigated, can be considered in patients in patients in whom more invasive techniques are restricted either due to anatomy, comorbidities, or inability to stop anticoagulation. |

## Relevant Anatomy

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| Where is the sphenopalatine ganglion located? | This is the largest of the four parasympathetic ganglions of the head and is located in the pterygopalatine fossa. |
| What are the borders of the pterygopalatine fossa? | Anteriorly located is the maxillary sinus, while posteriorly is the medial pterygoid plate. Superiorly located is the sphenoid sinus and medially is the palatine bone. |
| What is the location of passages that connect to the pterygopalatine fossa? | The pterygomaxillary fissure is located laterally and the foramen rotundum, which contains the maxillary nerve, is located superolaterally and posteriorly. The sphenopalatine foramen is located medially. The inferior orbital fissure is located superiorly and anteriorly. |
| What major vessel lies in the pterygopalatine fossa? | The maxillary artery and its branches. |
| What nerve fibers is the sphenopalatine ganglion composed of? | It is composed of sensory, sympathetic, and parasympathetic nerve fibers. |

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| What is the function of the sensory fibers from the sphenopalatine ganglion? | These fibers originate from primarily the maxillary nerve which passes through the sphenopalatine ganglion and innervates parts of the pharynx, the nasal membrane, soft palate, and parts of the hard palate. |
| What is the afferent and efferent sympathetic innervation of the sphenopalatine ganglion? | Afferent fibers originate from the superior cervical ganglion and run in the deep petrosal nerve, which ultimately joins with the greater petrosal nerve to form the vidian nerve which enters the ganglion. Efferent branches of the ganglion include the greater and lesser palatine nerves, pharyngeal branch of the maxillary nerve and nasopalatine nerve. |
| What is the afferent and efferent parasympathetic innervation of the sphenopalatine ganglion? | Parasympathetic nerve fibers within vidian nerve synapse on the sphenopalatine ganglia; post-ganglionic nerve fibers travel to deep branches of the trigeminal nerve which innervate the nasal mucosa, hard palate, soft palate, and uvula. In addition, post-ganglionic axons within the zygomatic nerve, a maxillary nerve branch, ultimately reach the lacrimal gland. |

## Relevant Materials

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| What basic pre-procedural tasks should be considered prior to starting procedure? | Patient positioning in supine position, IV access, consider fixation of head on table with adhesive tape and/or bands, sterile preparation of access site. |
| Which imaging modalities can be utilized for this procedure? | Fluoroscopic guidance is often used; however, fluoroscopy in conjunction with CT can also be considered in patients with complex anatomy. |

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| Which drugs and needles should be available for a therapeutic nerve block? | 1. 25-gauge 1.5-inch needle along with a 5 ml syringe and 1% lidocaine or 0.25% bupivacaine for local anesthetic at the access site<br>2. 22-gauge 10 cm nerve block needle<br>3. 1 mL of nonionic water-soluble contrast (check the patient's allergy history) |
| Which approach is utilized for radiofrequency thermocoagulation and radiofrequency pulsation? | Infrazygomatic approach. |
| What type of needle is utilized in radiofrequency lesioning? | Insulated RF needle with either a 3 mm or 5 mm tip. |
| Which RF needle tip size is preferred? | 3 mm tip is generally preferred to avoid damage to adjacent nerves. |
| What materials are involved in an intranasal approach? | Cocaine is a good anesthetic to use due to its vasoconstrictive properties. A cotton tipped applicator is utilized to go through the nares. Lidocaine, bupivicaine, or ropivicaine may also be used. |

## General Step by Step

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| What approaches are available for sphenopalatine ganglion nerve block? | Intranasal, transnasal, and infrazygomatic techniques can be utilized. |

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| What type of procedural anesthesia is required? | Local anesthesia as well as light sedation with fentanyl and/or midozalam may be required. Some cases may require monitored anesthesia care. |
| For the infrazygomatic approach, which anatomical region should be prepped? | The ipsilateral side of the nose to the ear all the way and inferiorly towards the mandible. Most experts recommend leaving the ipsilateral eye open to be able to recognize possible retrobulbar hematoma. |
| What initial images should be obtained? | A true lateral fluoroscopic view should be obtained and the pterygopalatine fossa visualized. The mandibular notch should also be able to be seen. |
| How should access begin? | Local anesthesia to the soft tissue overlying the mandibular notch should be obtained. Subsequently, a small angiocatheter with metal portion removed. A block needle then is advanced medially, anteriorly, and slightly cranially toward the pterygopalatine fossa. |
| Where should the operator park the block needle? | Obtain an AP fluoroscopic image. The block needle should be advanced toward the middle turbinate and stop just short of or adjacent to the palatine bone. |

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| What is the transnasal approach? | This involves initially anesthetizing the entry from the nares to the nasopharynx with a cotton-tipped applicator (similar to intranasal approach, which is not an invasive technique and thus will not be described in detail in this section). Subsequently, a 26-gauge needle is advanced within a surrounding sheath until it reaches the posterolateral nasopharyngeal wall with the bevel of the needle facing laterally. Advance further with the needle and inject contrast to confirm positioning in the pterygopalatine fossa and subsequent administration of anesthetic and/or steroid. |
| Once appropriate positioning has been obtained, what is the next step? | Injection of 1 ml of contrast to ensure the needle is not intravascular. Injection of local anesthetic with or without steroid can then be performed. |
| What indications suggest a successful diagnostic and therapeutic block? | Ipsilateral conjunctival injection, nasal congestion, and lacrimation and resolution of pain. If the pain does not subside, this may mean the cause of the patient's symptoms are unrelated to the sphenopalatine ganglion. |

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| What is a stimulation test relative to RF thermocoagulation and pulsed radiofrequency? | A stimulation test allows the operator to optimally confirm electrode positioning. Parasthesias in the nose indicated appropriate positioning. Parasthesias in the hard palate indicate palatine nerve stimulation and the electrode should be redirected cephalad and medial. Stimulation in the upper lip indicates maxillary nerve stimulation and the electrode should be redirected caudal and medial. This should be performed at 45–55 Hz at greater than 0.2 V and less than 1 V. |
| Once proper positioning is confirmed, what is the next step for RF thermocoagulation? Pulsed radiofrequency? | Injection of 0.5–1 mL of 1 percent lidocaine. After a 1-minute interval, begin lesioning at 70–80 degrees Celsius for 2 cycles of 60–90 seconds. Pulsed radiofrequency can be performed in 120–150 second cycles for 2–4 cycles at a temperature of 42 degrees Celsius. |

## Complications

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| Why is epistaxis a risk factor with the transnasal approach? | The soft intranasal tissue can easily be injured if the electrode or needle is advanced too firmly or protrudes too far outside of the sheath prior to adequate positioning. |
| What will occur if the RF needle is directed superolaterally? | Injury to the maxillary nerve resulting in long-term parasthesias if sensory stimulation is not performed. |
| Why is an aspiration test necessary once the operator believes they are in the proper space? | To avoid inadvertent intravascular injection of anesthetic. |

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| What major artery is at risk for puncture in the pterygopalatine fossa? | The maxillary artery and its branches. |
| The operator may see that the patient is bradycardic during RF lesioning. Is this normal? | This may occur in some patients and should subside once lesioning is over. |
| What postprocedural complications can occur? | Hematoma involving the cheek due to puncture of arterial supply or venous plexus, transient double vision secondary to local spread of anesthetic, and infection are all possibilities. Hypesthesia of the palate and pharnyx secondary to RF lesioning is also possible. |
| What is the risk of infection? | Overall, the rate of infection is not significantly different than other similar procedures. |

## Landmark Research

Sanders M, Zuurmond W. Efficacy of sphenopalatine ganglion blockade in 66 patients suffering from cluster headache: a 12- to 70-month follow-up evaluation. J Neurosurg. 1997;87:876–80.

- This case series by Sanders and Zuurmond described 66 total patients with episodic and chronic cluster headaches. 34 of 56 patients with episodic headaches and 3 out of ten patients with chronic cluster headaches showed complete relief of symptoms at 29 months.

Bayer E, Racz GB, Day M, et al. Sphenopalatine ganglion pulsed radiofrequency treatment in 30 patients suffering from chronic face and head pain. Pain Pract. 2005;5:223–7.

- Bayer and colleagues studied pulsed radiofrequency of the SPG in 30 patients with chronic face and head pain which showed that over 85 percent of patients had mild to moderate or greater pain relief. Nearly 2/3 of patients had reduction in the amount of pain medications they needed to take.

## Common Questions

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| How long after the procedure does the patient have to be observed? | A minimum of 2 hours. It is important to monitor vital signs. In addition, documentation of pain relief is also important. |
| What information should be relayed to the patient's caretakers? | Important information in regard to follow-up as well as information on possible post-procedural symptoms and complications as described in the above-related section. |
| When can RF thermocoagulation or pulsed radiofrequency be considered? | If block with anesthetic and/or steroid is successful in helping treat patient's pain, it can be inferred that pain may be related at least in part to the sphenopalatine ganglion. A more permanent lesioning of the ganglion may be thus be considered. |
| Which patients may need multispecialty evaluation and input prior to an invasive nerve block procedure? | Patients who are on anticoagulants. It is important to consider the risks versus benefits in regard to performing any procedure including pre-procedural discontinuation of anticoagulant therapy. |

## Further Reading

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