Diagnostic Imaging

Interventional Procedures

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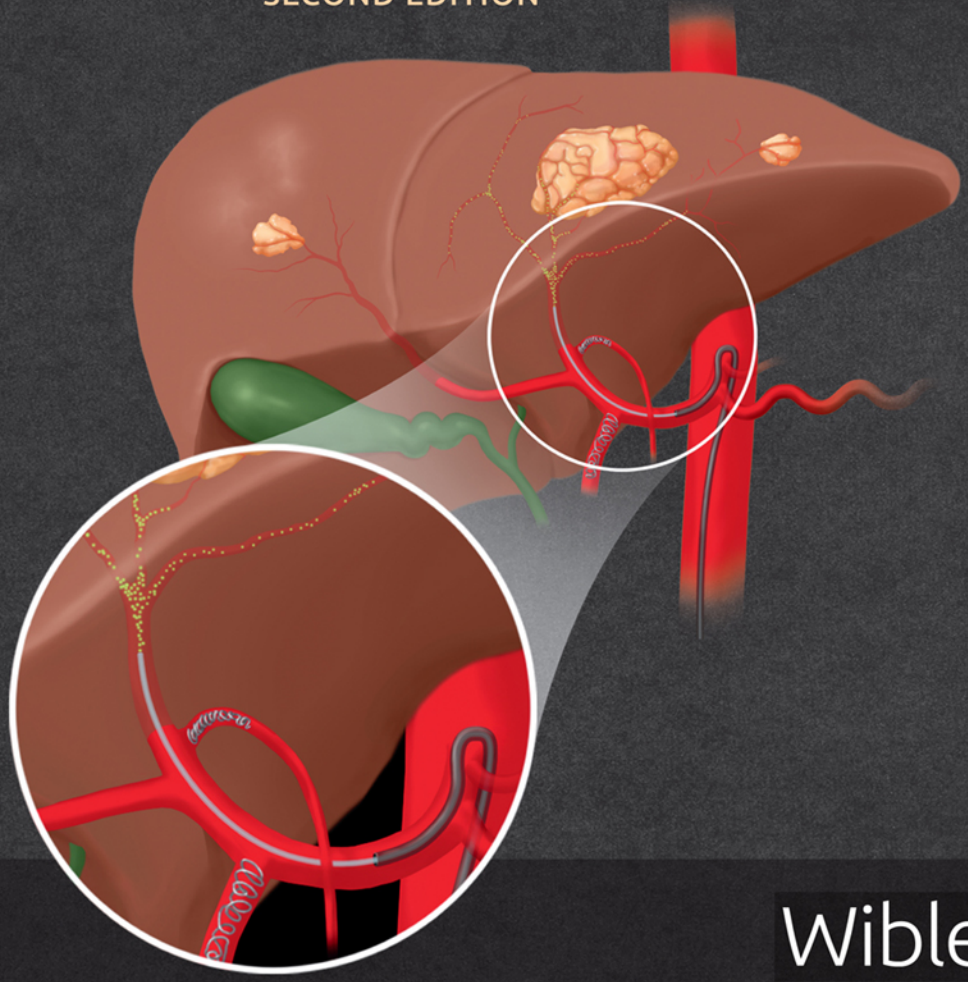

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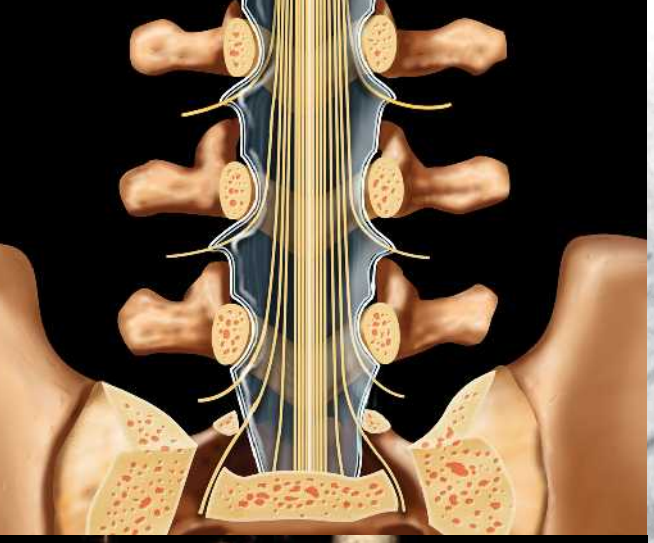

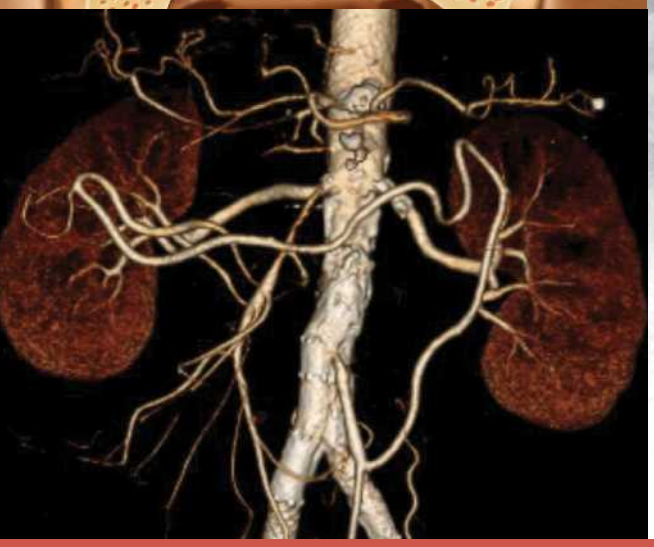

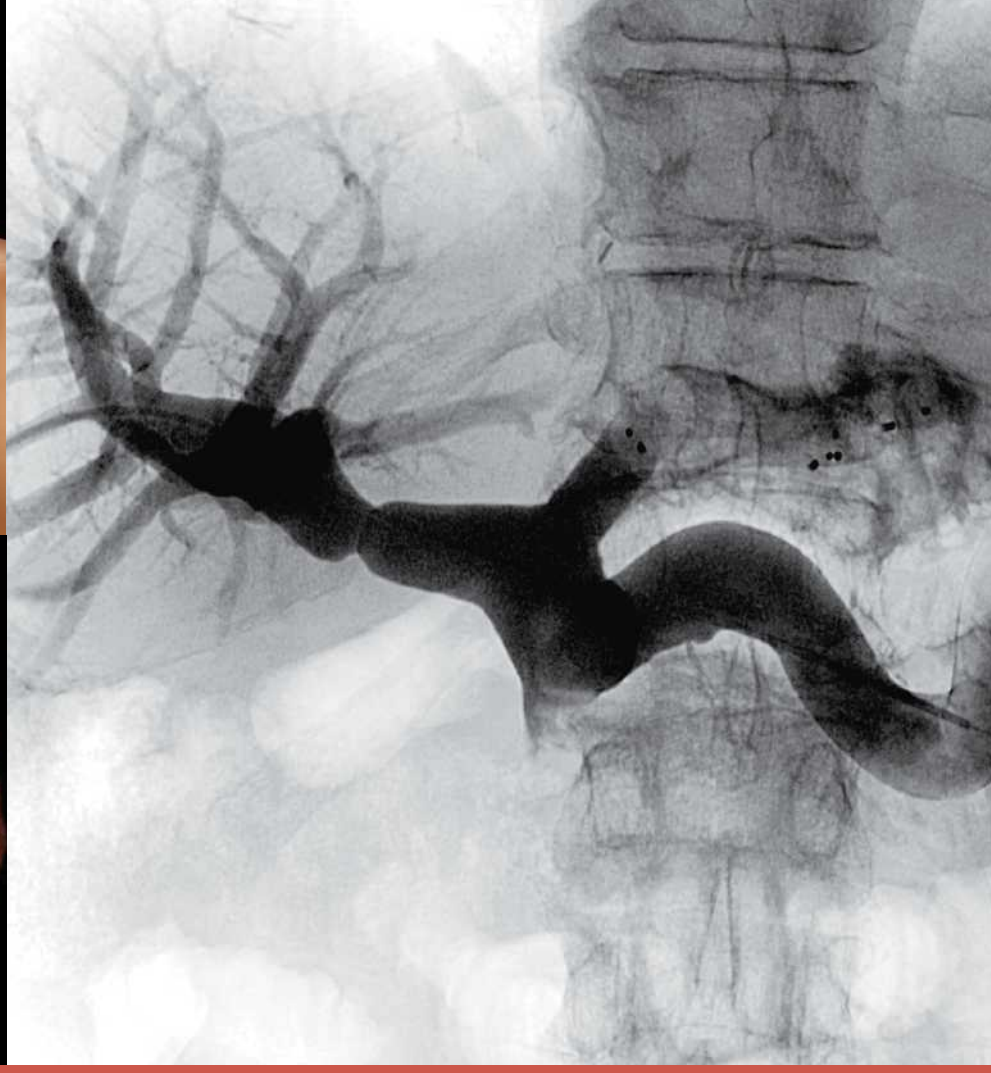

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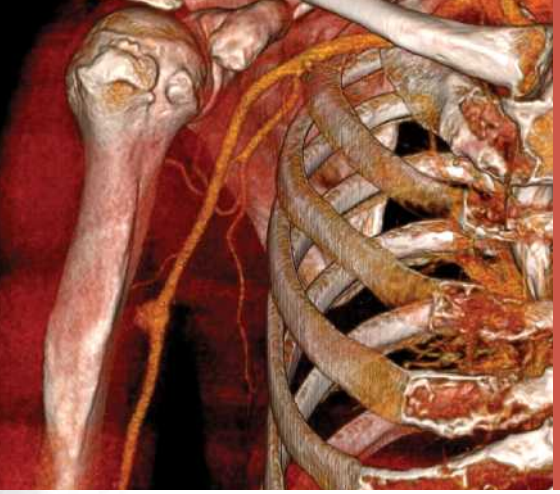

Diagnostic Imaging

Interventional Procedures

SECOND EDITION

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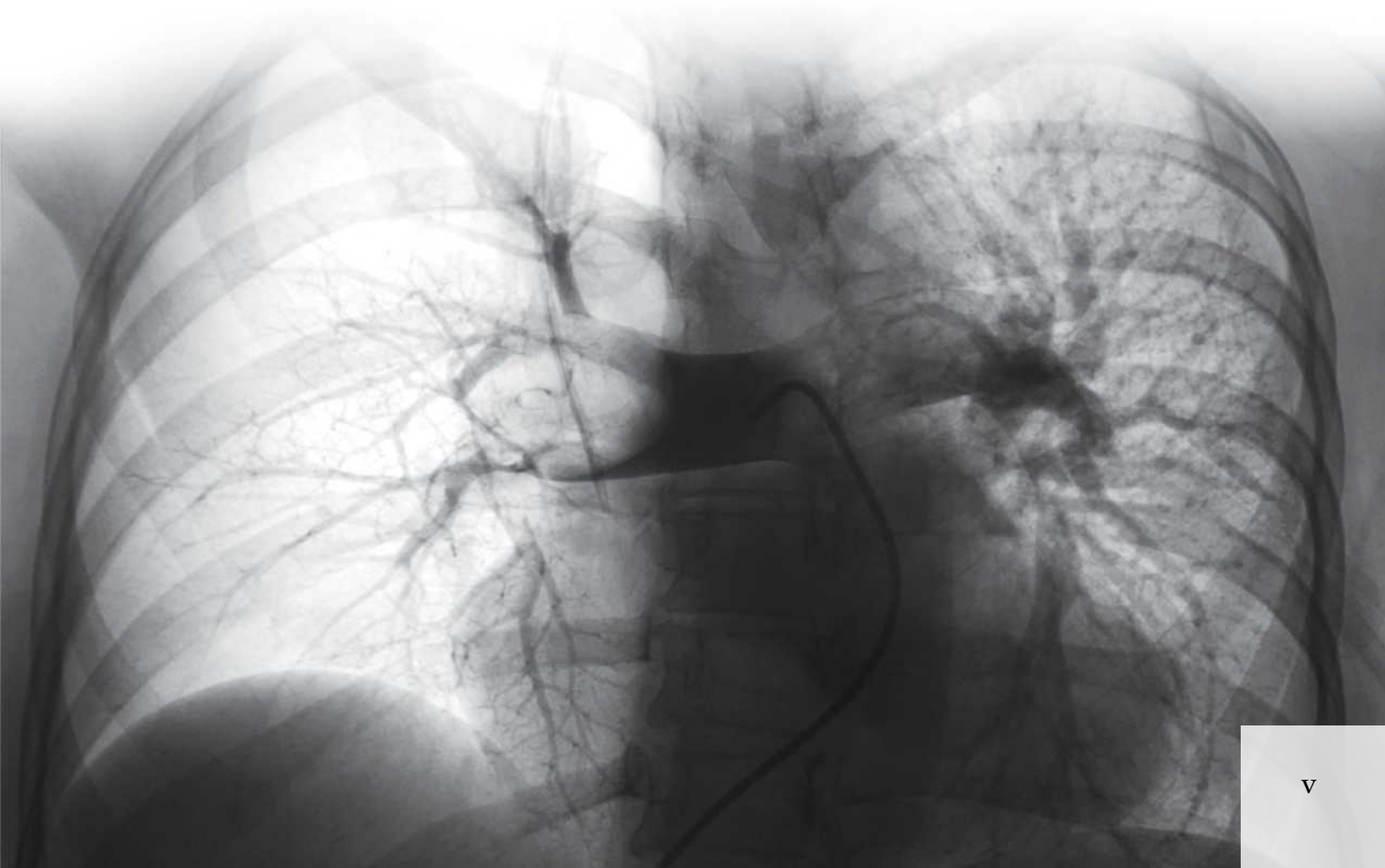
Dedication

To Helen, Brayden, Brighton, and family not-so-extended,
for your faith, support, and encouragement.

To friends and mentors, for years of enlightenment
and inspiration.

And to the United States Peace Corps.

BCW



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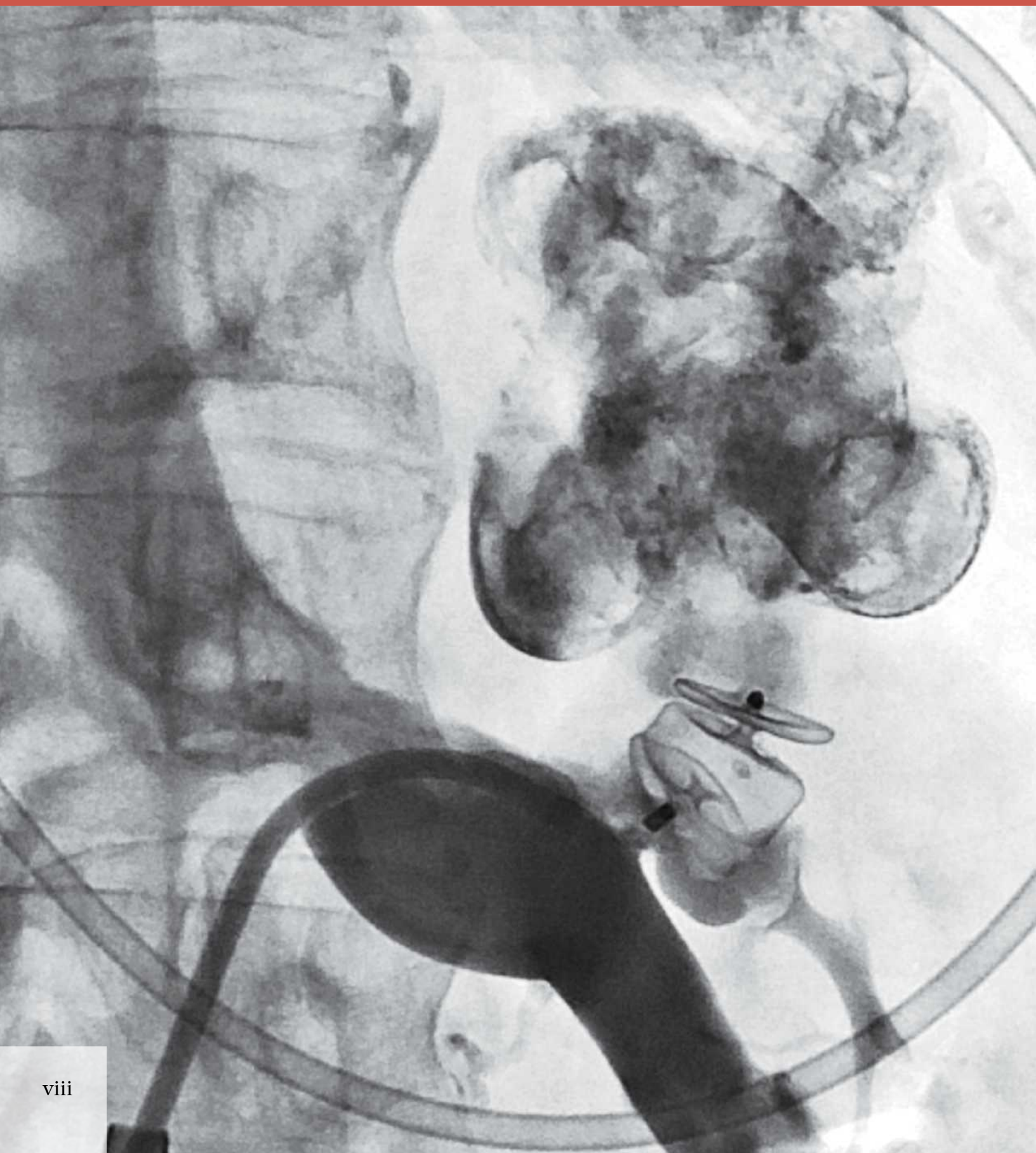

Preface

Welcome to *Diagnostic Imaging: Interventional Procedures*, second edition! Designed as a "how-to" guide and searchable reference, this second edition has been authored to be instrumental to trainees and seasoned interventionalists. The format remains true to the first edition created by T. Greg Walker, MD, FSIR and his team. The text encompasses the extensive scope of vascular and nonvascular procedures expected of a busy interventional practice, covering topics in a comprehensive and detailed fashion. Succinct text, bullet points, and subdivided chapters also allow rapid search of pre- and postprocedural concepts.

Updates in our second edition include over 800 new high-resolution case images and numerous new full-color graphics. Procedures described within the text are illustrated with step-by-step case examples that have been updated and optimized. Procedure-specific references, interventional techniques and equipment, and expected procedural outcomes have been updated as well. Additionally, new chapters have incorporated supplemental topics such as procedural medications, lumbar puncture, celiac plexus block, and sacroplasty.

Diagnostic Imaging: Interventional Procedures, second edition includes contributions from several first-edition authors practicing at Massachusetts General Hospital, plus new physician authors from Johns Hopkins University, University of Pennsylvania, University of Utah, University of Missouri-Kansas City, and University of Wisconsin, in addition to several seasoned authors who have found their way to private practice. I am eternally grateful to these authors for their dedication, professionalism, and hard work. Additional credit and gratitude goes out to the team of editors and illustrators at Amirsys/Elsevier, setting the *Diagnostic Imaging* series of textbooks apart from any others currently available.

I am especially grateful to Dr. Walker, who recommended I lead authorship of the second edition of his text. After years as a team leader for Amirsys' RADPrimer, a contributing author to STATdx, and director of our interventional radiology curriculum and medical student rotation, I have always found case examples to be one of the best learning tools for our trade. The opportunity to update a textbook flush with case images and outstanding graphics appealed to me greatly, and I have since found the process to be a rewarding experience. I hope that you will find the second edition of *Diagnostic Imaging: Interventional Procedures* to be a valuable addition to your practice.

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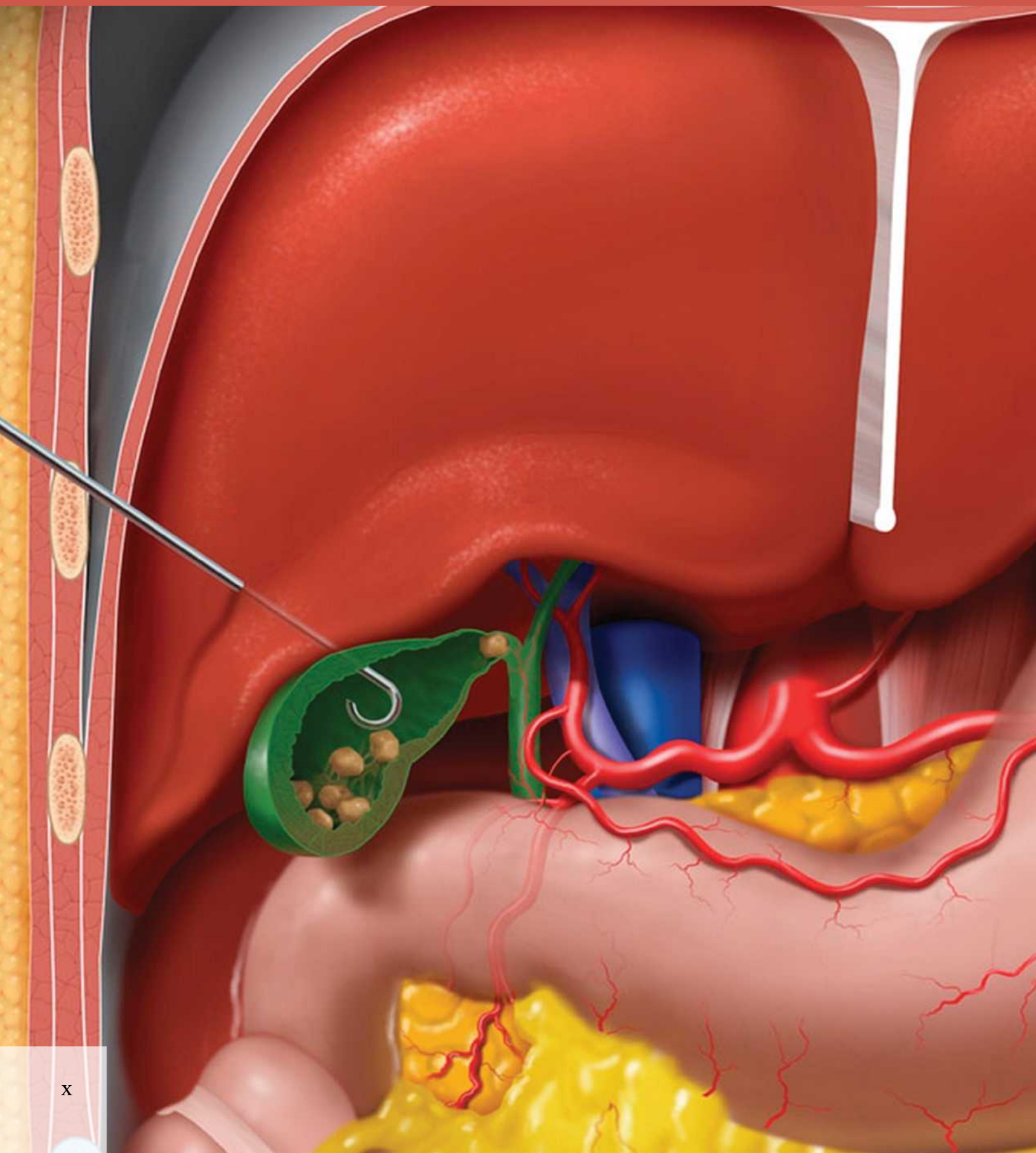

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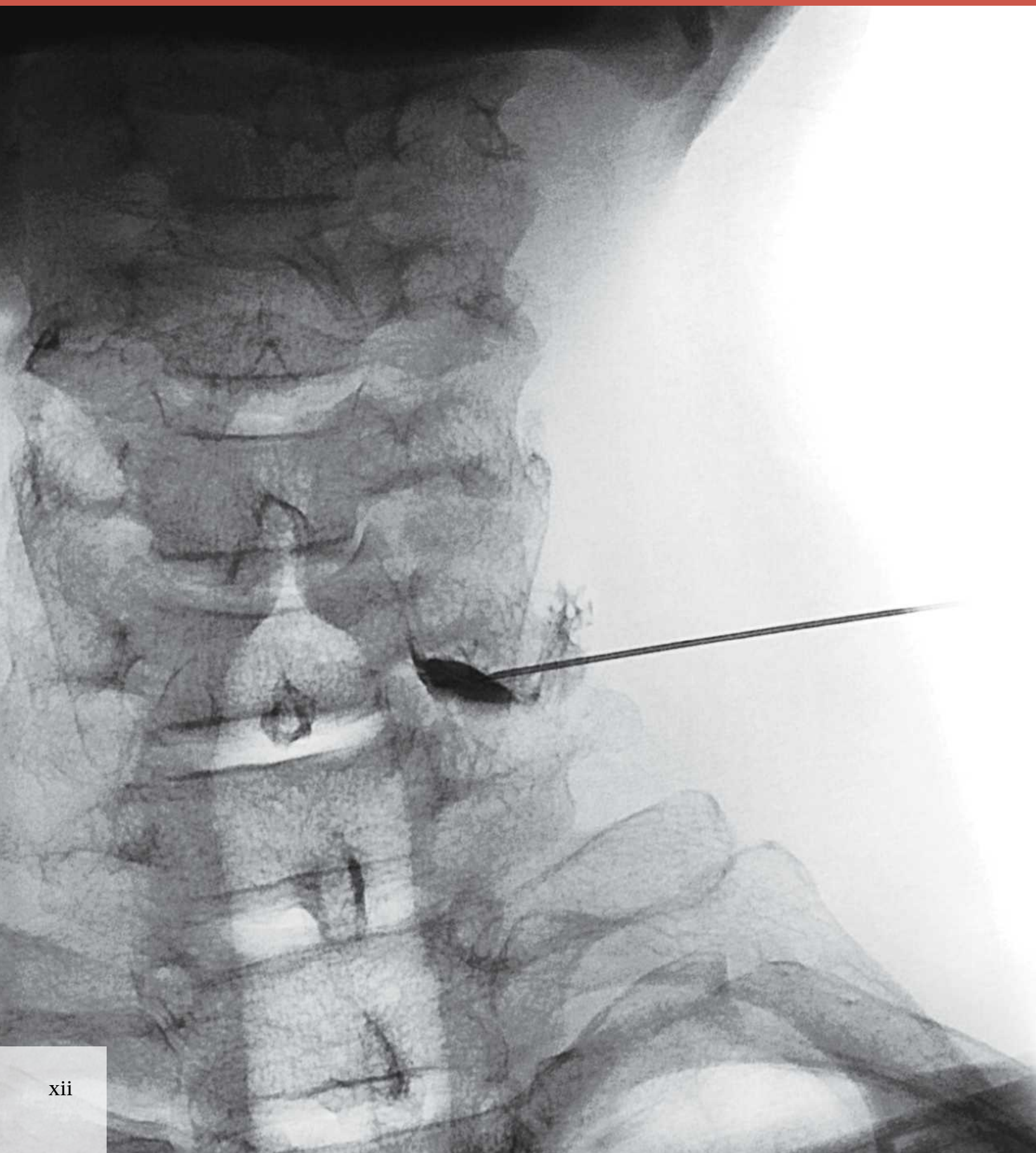

Sections

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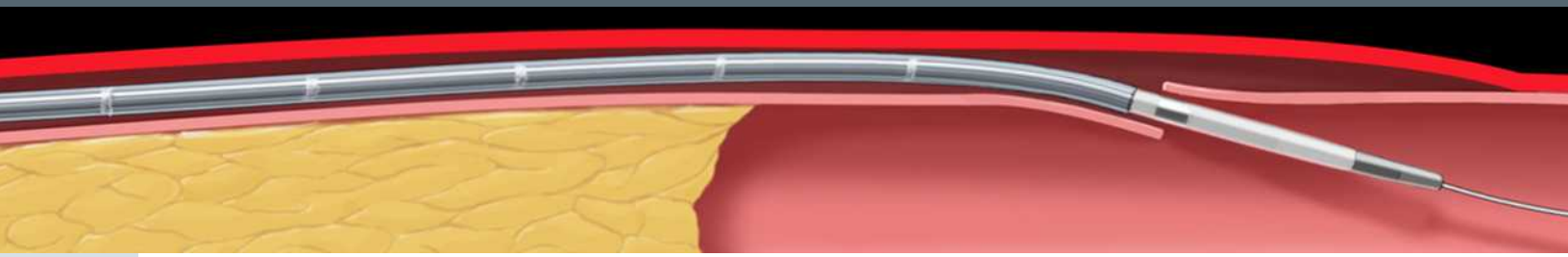

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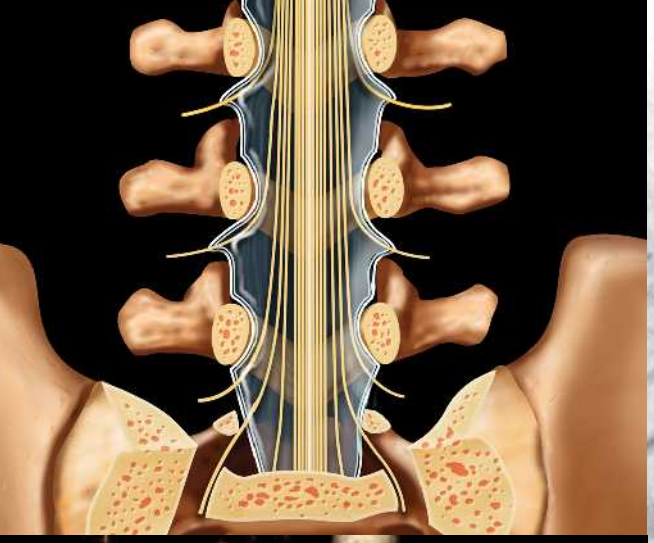

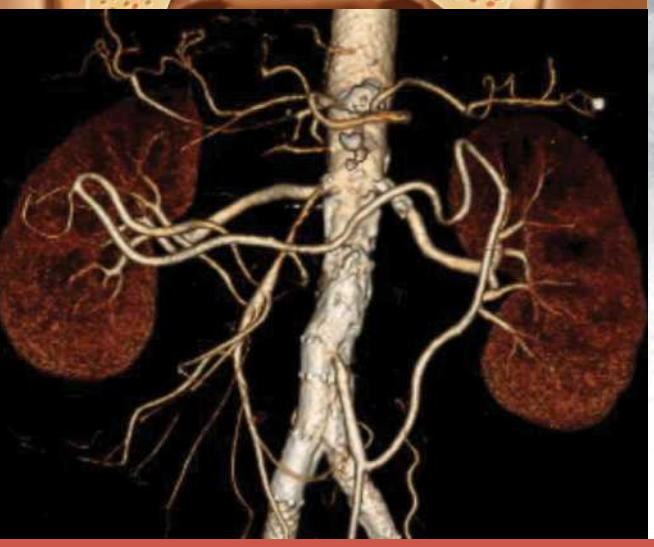

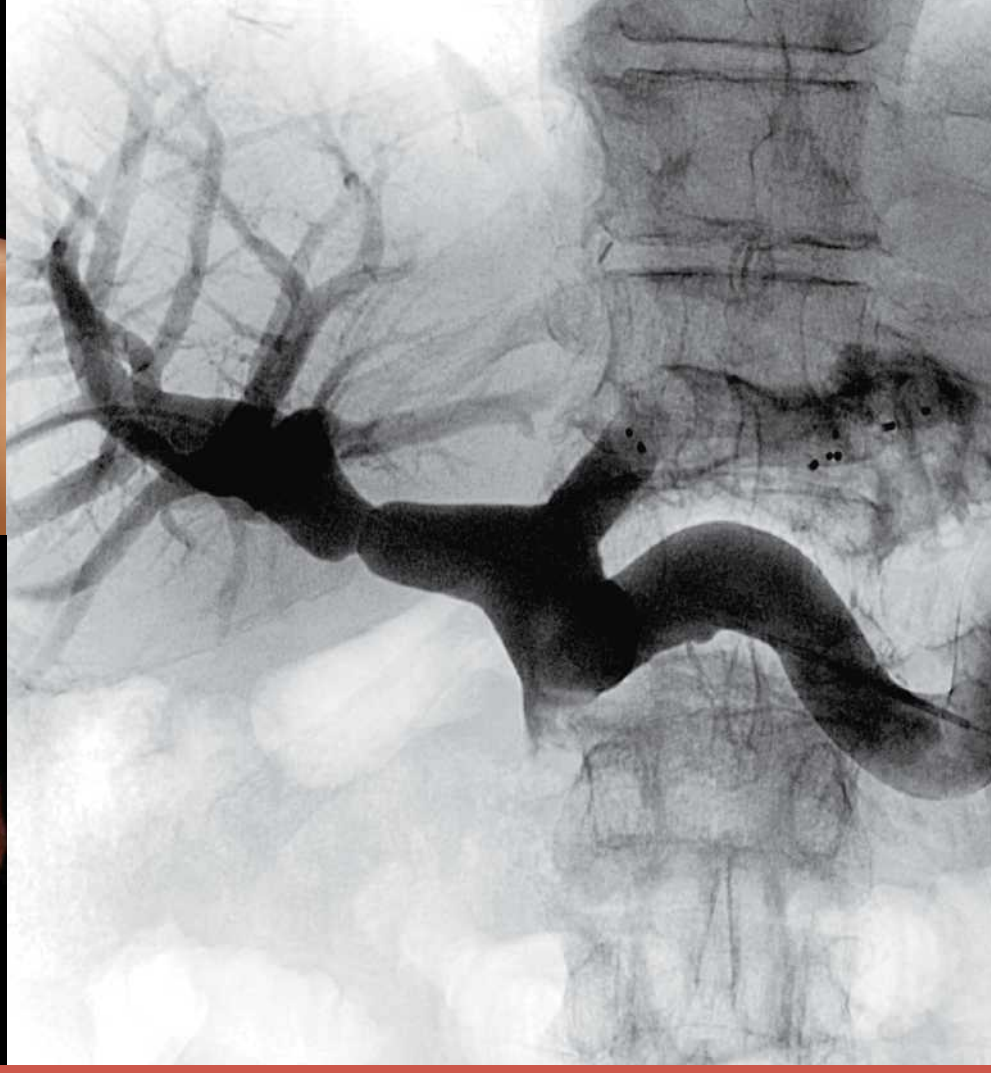

Diagnostic Imaging

Interventional Procedures

SECOND EDITION

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SECTION 1

General Principles

Procedural Considerations

Procedural Techniques

KEY FACTS

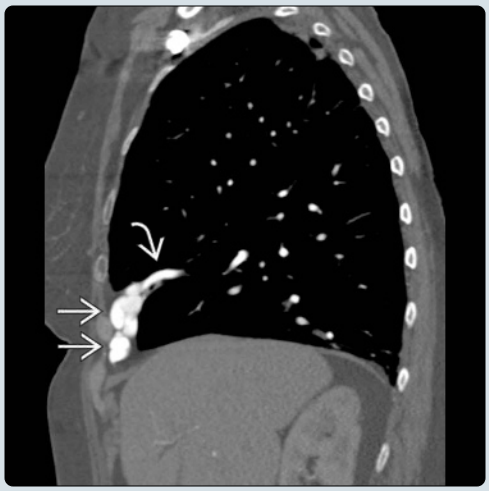
UTILITY OF PREPROCEDURE IMAGING

- Mapping of normal & abnormal anatomy
- Obtaining physiologic information
- Used for planning of interventional procedures
  - Determination of appropriate device type & size

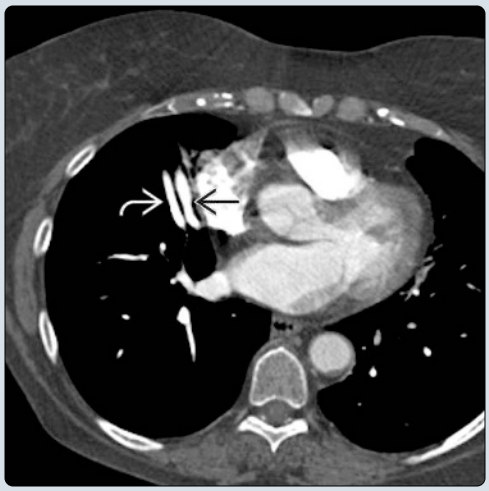
PREPROCEDURE IMAGING OPTIONS

- **Ultrasound**: Includes grayscale, color Doppler, intravascular ultrasound
  - Advantages: Noninvasive, excellent tissue contrast
  - Disadvantages: Window limits, operator dependent
- **Intravascular ultrasound**: Used with angiography
  - Advantages: Depicts intraluminal characteristics
  - Disadvantages: Invasive, added expense & time
- **Echocardiography**: Includes transthoracic & transesophageal echocardiography
  - Advantages: No radiation or contrast agents needed
  - Disadvantages: Limited 3D capability
- **CT**: Includes CTA/CTV
  - Advantages: Excellent 3D spatial resolution
  - Disadvantages: Ionizing radiation, requires contrast
- **MR**: Includes MRA/MRV
  - Advantages: Best tool for tissue characterization
  - Disadvantages: Decreased spatial resolution, expensive, time intensive
- **DSA**: Includes cone beam CT
  - Advantages: Guidance for vascular interventions
  - Disadvantages: Invasive, requires contrast
- **Radionuclide scintigraphy**: Includes scintigraphy, 3D single-photon emission CT, and PET
  - Advantages: Physiologic information
  - Disadvantages: Radioisotope exposure

PAVM: Preprocedure Planning (CTA)

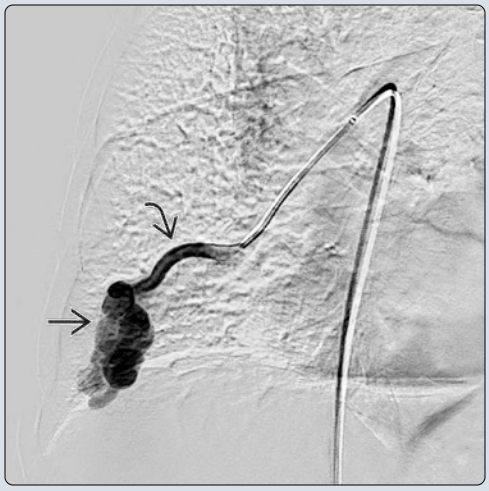


PAVM: Preprocedural Planning (CTA)

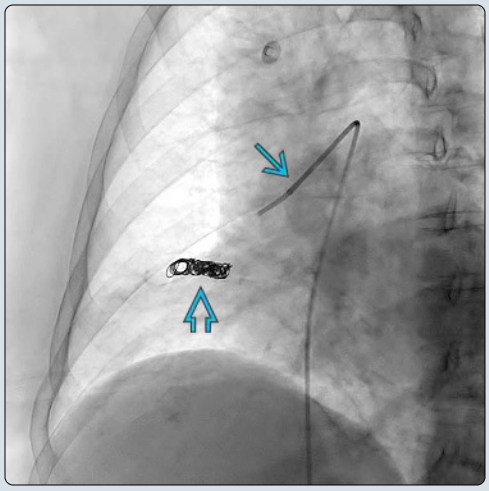


(Left) *Sagittal CTA of the chest demonstrates a prominent pulmonary arteriovenous malformation (PAVM) with a discrete, single feeding pulmonary artery.* **(Right)** *Axial CTA of the same patient demonstrates the feeding artery and draining vein of the right lower lobe PAVM. This noninvasive preprocedural CT allows assessment of feeding vessel caliber and location. Careful planning for the intervention ultimately results in decreased procedural time, contrast, and radiation exposure.*

PAVM: Procedural Angiogram



PAVM: Postembolization



(Left) *Selective DSA in the same patient demonstrates the right lower lobe PAVM once the feeding pulmonary artery branch is selected. There is excellent correlation with the preprocedure CTA used for planning.* **(Right)** *Embolization coils were used to occlude the feeding artery of the PAVM. The sheath and catheter are positioned within the feeding artery.*

INTRODUCTION

Preprocedure Imaging Options

- Preprocedure imaging should be obtained prior to many vascular or nonvascular interventions
  - Mapping of normal/abnormal anatomy/physiology
  - Used for procedure/intervention planning
  - Determination of optimal device size & configuration
- Wide spectrum of imaging options available
  - **Ultrasound**
    - Includes grayscale & color Doppler
  - **Intravascular ultrasound**
    - Typically used concurrently with angiography
  - **Echocardiography**
    - Includes transthoracic echo or transesophageal echo
  - **CT**
    - Includes nongated/gated CTA/CTV
  - **MR**
    - Includes MRA/MRV
  - **DSA**
    - Includes C-arm-based cone beam CT
  - **Radionuclide scintigraphy**
    - Includes scintigraphy, 3D single-photon emission CT, and PET
- Examples of interventions highly dependent on preprocedure imaging for optimal outcomes
  - Vascular malformations
  - Carotid artery stenting (CAS)
  - Abdominal endovascular aneurysm repair (EVAR)
  - Thoracic endovascular aortic repair (TEVAR)
  - Transarterial chemoembolization (TACE)
  - Radioembolization
  - Endovenous thermal varicose vein ablation (EVTA)
  - Percutaneous transhepatic biliary interventions
  - Transjugular intrahepatic portosystemic shunt (TIPS)
  - Uterine artery embolization (UAE)

IMAGING MODALITIES

Ultrasound

- Advantages
  - No radiation exposure
  - Low cost; readily available
  - Excellent delineation between solid & fluid-filled spaces
  - Real-time imaging
- Disadvantages
  - Acoustic window restrictions
  - Operator dependent
  - Patient body habitus dependent

Intravascular Ultrasound

- Advantages
  - Allows accurate visualization of vascular lumen
  - Accurately depicts intraluminal/mural abnormalities
  - Accurate assessment of intravascular device position
- Disadvantages
  - Invasive compared to conventional US
  - Adds procedural expense
  - Adds additional procedural time

Echocardiography

- Transthoracic or transesophageal options
  - Transesophageal requires sedation; invasive
- Advantages
  - Allows flow velocity quantification/gradient calculations
  - No radiation or contrast agents needed
- Disadvantages
  - Acoustic window restrictions
    - Various available acoustic windows: Intercostal spaces, liver, epigastrium, or suprasternal notch
    - Cannot evaluate entire aortic arch/great vessels
    - Limited 3D capability compared to MR/CT

CT

- Advantages
  - Accurately demonstrates vascular anatomy
  - Has excellent 3D spatial resolution
  - Allows post hoc image reconstructions in any plane
  - Best test for imaging of calcium
- Disadvantages
  - Requires iodinated contrast to evaluate vasculature
  - Uses ionizing radiation
  - Ascending aorta pulsation artifacts/pseudoflaps
- Contraindications
  - Severe allergy to iodinated contrast
  - Renal insufficiency
    - Estimated glomerular filtration rate (eGFR) > 60: No contraindication to contrast administration
    - eGFR > 30 & < 60: May proceed with precautions/hydration

MR

- Advantages
  - Phase-contrast imaging allows flow quantification
  - Allows cardiovascular evaluation without IV contrast
  - Best tool for tissue characterization
    - Soft tissue contrast resolution superior to CT
  - May use despite iodinated contrast allergy
- Disadvantages
  - Long procedure; often requires several breath holds
  - High cost; not readily available
  - Inferior spatial resolution
  - Artifacts may mimic disease
  - Does not evaluate calcium well
  - Poor access to patient during examination
    - Difficult life support/monitoring in severely ill
  - Motion sensitive due to long acquisition times
    - May require sedation
- Contraindications
  - Severe claustrophobia
  - Medical implants (e.g., pacemakers, programmable ventricular shunts, medication pumps, brain aneurysm clips)
  - Cannot use gadolinium contrast if renal failure
    - Risk of nephrogenic systemic fibrosis

DSA

- Advantages
  - Guidance for performing vascular interventions
  - Real-time information regarding hemodynamics

- Disadvantages
  - Invasive
    - If sole planning modality, may require staged procedure
  - Ionizing radiation
    - Exposure to patient & procedural personnel
  - Requires administration of intravascular contrast
    - Iodinated contrast typically used
    - May also use CO_2
    - Potential for contrast allergy/anaphylaxis or contrast-induced nephropathy
  - Underestimates vascular calcifications/mural thrombus
  - Can have significant image quality issues due to misregistration artifacts (e.g., motion from patient, bowel, respirations)

Radionuclide Scintigraphy

- Advantages
  - Provides physiologic information
    - PET images uptake of labeled fluorodeoxyglucose (FDG), a glucose analogue; neoplasms are highly metabolic/rapidly synthesize FDG
    - Technetium (Tc-99m) labeled red blood cell scan detects active gastrointestinal bleeding
- Disadvantages
  - Radioisotope exposure
  - Highly sensitive but may be nonspecific

PLANNING FOR SPECIFIC PROCEDURES

Vascular Malformations

- Cross-sectional (CTA/MRA) or ultrasound mapping of vascular anatomy
  - Delineation of inflow artery(ies) & outflow vein(s)
    - Demonstration of nidus & its communications
  - Determination of hemodynamic characteristics
    - High flow vs. low flow
    - Simple vs. complex

Carotid Artery Stenting

- Stenosis severity determined with various modalities
  - Color Doppler ultrasound with spectral analysis
  - CTA/MRA
    - Includes CTA reformations
    - Maximum intensity projections
    - Stenosis severity calculations
  - Digital subtraction angiography
    - Typically combined with CAS procedure
  - Stent choice often based on preprocedural CTA/MRA measurements & arterial anatomy
    - Various stent designs, configurations, & lengths exist
    - Vessel diameters important for sizing stent appropriately for target vessel
  - Embolic protection device (EPD) choice based on CTA/MRA measurements & arterial anatomy
    - Various types of EPDs
    - Vessel diameters & lengths important for sizing EPD appropriately for target vessel

Abdominal Endovascular Aneurysm Repair

- Endograft choice based on CTA/MRA measurements
  - Endograft diameter based on true aortic short axis
    - Measured immediately below lowest renal artery
    - 10-20% oversizing to ensure good graft apposition
- Proximal landing zone requires ≥ 10-mm long segment of normal aortic diameter
- External iliac artery diameter ≥ 7 mm for access
  - Most device delivery systems ≥ 18 Fr
  - Circumferential/excessive calcification limits access
- Excessive iliac artery tortuosity may complicate access
- Aneurysm neck morphology, angulation, & length are determinants of proximal seal zone suitability
  - Neck angulation > 60° is contraindication
  - Nontapered necks most favorable anatomy
  - Reverse tapered (conical) neck problematic
  - Mural thrombus & excessive calcifications problematic
- Bifurcated endografts require minimal distal aortic diameter (a.k.a. distal neck)
  - Can place aortouniiliac graft in small caliber distal aorta, combined with cross-femoral graft
- Branch vessel patency & location can be determined
  - Relationship of renal arteries to neck is critical
  - Large lumbar arteries & patent inferior mesenteric artery may predispose to type II endoleak
- Abdominal aortic aneurysm (AAA) measurements generally include (but not limited to)
  - **Diameters**: Aneurysm neck; aorta at bifurcation; maximal aneurysm diameter; common iliac, external iliac & common femoral arteries
  - **Length**: Lowest renal artery to aneurysm (neck length); lowest renal artery to aortic bifurcation; lowest renal artery to iliac bifurcation
  - **Angles**: Proximal & distal neck angulation; excessive iliac artery angulation

Endovenous Thermal Varicose Vein Ablation

- Preprocedure duplex US imaging
  - Mapping of venous anatomy
  - Assessment of valve closure times & venous reflux
  - Evaluation for incompetent perforators
  - Evidence of postthrombotic obstruction
  - Evaluation for deep & superficial venous thrombosis
- Cross-sectional imaging: CTV/MRV
  - Suspected pelvic/abdominal venous outflow disease
  - EVTA ineffective if venous outflow compromise

Transhepatic Biliary Interventions

- Preprocedure duplex US imaging
  - Demonstrates biliary ductal anatomy
- Cross-sectional CT/MR imaging
  - Demonstrates etiology of biliary obstruction
  - MR cholangiopancreatography useful for preprocedure biliary anatomy
- Hepatobiliary scintigraphy
  - Assessment for biliary leak

Radioembolization

- Targeted treatment for nonoperable primary & secondary hepatic malignancies
  - Preprocedure CECT or contrast-enhanced MR evaluation of tumor burden
    - Used to calculate dose of radioactivity to be delivered
  - CTA/MRA evaluation of vascular anatomy

- Evaluate for variant anatomy
- Hepaticoenteric arterial communications

- Prophylactic embolization of hepaticoenteric arterial communications
  - Elimination of potential pathways for nontarget embolization of injected radioactive spheres
- Injection of Tc-99m macroaggregated albumin via catheter placed in intended position for radioembolization
  - Followed by radionuclide lung perfusion scan; evaluates lung shunt fraction

Thoracic Endovascular Aortic Repair

- Used for treatment of aneurysm, transection, type B dissection, intramural hematoma, penetrating ulcer
  - Requires satisfactory proximal seal zone
  - May require endograft coverage of left subclavian artery to achieve adequate proximal seal zone
    - Requires vertebral & carotid duplex US; assess if left common carotid to left subclavian artery bypass or left subclavian transposition needed
  - May require debranching of aortic arch to achieve adequate proximal seal zone
  - Requires satisfactory distal landing zone
    - Need 20-mm distal seal zone
  - Endograft choice based on CTA/MRA measurements
    - Endograft diameter based on true aortic short axis
      - Determination of aortic diameter at proximal & distal seal zones of endograft
    - Determination of length of coverage required
    - Assessment of aortic angulation & tortuosity
    - Mural/luminal characteristics of aorta (e.g., thrombus burden, calcifications)
    - Characterization of access vessels
      - Common femoral/iliac artery diameters/tortuosity/calcifications

Transcatheter Arterial Chemoembolization

- Targeted treatment for inoperable primary & secondary hepatic malignancies
  - Preprocedure CECT or contrast-enhanced MR evaluation of tumor burden
    - Need liver parenchyma involvement of < 50%
    - Assess degree of tumor enhancement
      - Hypervascular tumors have better response
  - CTA/MRA evaluation of vascular anatomy
    - Determine arterial supply to tumor(s)
    - Evaluate for variant anatomy
    - Evaluation of portal vein patency

TIPS Creation

- Percutaneously created connection within liver between portal & systemic circulations
  - Preprocedure ultrasound
    - Ultrasound confirmation of portal vein patency
    - Color Doppler US evaluates direction of portal flow (e.g., hepatopetal vs. hepatofugal flow)
    - Presence/absence of ascites
  - Cross-sectional imaging: CT or MR
    - Confirms portal vein patency
    - Evaluates for competing portosystemic shunts
    - Demonstrates location & extent of varices
    - Shows portal & hepatic vein anatomic relationship
      - Allows optimal hepatic to portal vein intraprocedural puncture trajectory
    - Evaluates for extrahepatic portal bifurcation
      - Risk of intraperitoneal hemorrhage if extrahepatic portal vein puncture

Uterine Artery Embolization

- Transcatheter delivery of particles to embolize uterine artery
  - Preprocedure contrast-enhanced MR evaluation of female pelvis
    - Location of fibroids: Submucosal, subserosal, pedunculated, etc.
    - Fibroid size; compression of adjacent structures
    - Vascularity of fibroid; predictive of UAE response
    - Adenomyosis: Junctional zone > 12 mm
  - Pelvic ultrasound
    - Assessment of fibroids: Location, vascularity, size
    - Doppler of uterine cavity (postpartum hemorrhage)
  - CT if claustrophobic patient or MR contraindication
  - Digital subtraction angiography
    - Performed concurrently with embolization
    - Ovarian artery contribution to fibroids
    - Evaluation of utero-ovarian anastomoses

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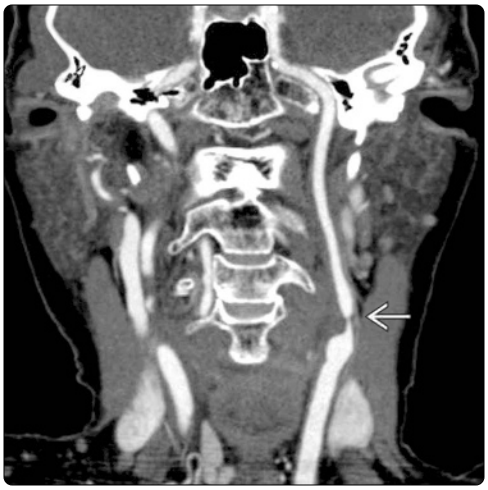
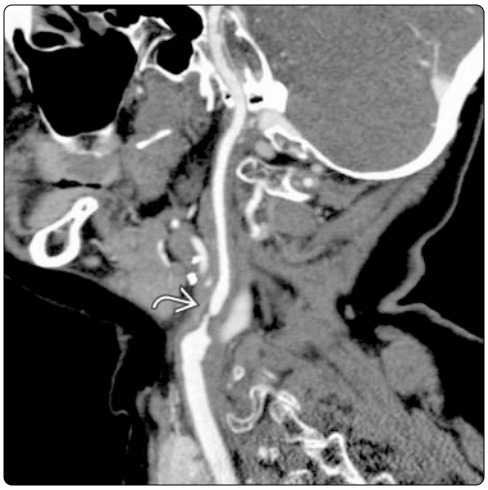
Carotid Artery Stent: Preprocedural Planning (Coronal MIP from CTA)

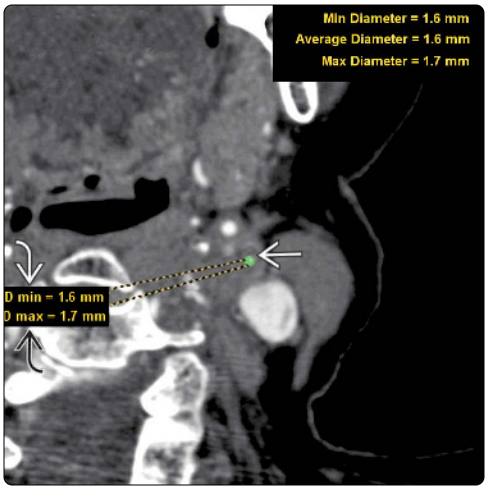


Carotid Artery Stent: Preprocedural Planning (Sagittal MIP from CTA)

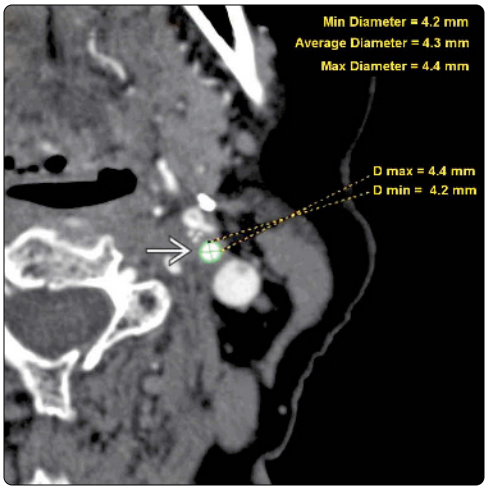


(Left) *Cross-sectional imaging and multiple reformations are important in preprocedure planning for carotid artery stenting. This coronal maximum intensity projection (MIP) shows a severe stenosis of the left internal carotid artery (ICA) with normal caliber of the ICA distally and the common carotid artery proximally.* **(Right)** *Sagittal MIP confirms the severe stenosis and a normal-caliber distal left ICA. The arterial caliber impacts the types and sizes of stent and embolic protection devices chosen.*

Carotid Artery Stent: Preprocedural Planning (Calculation of Stenosis Severity)

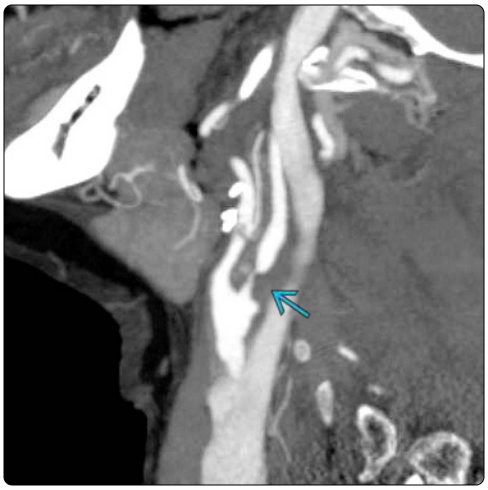


Carotid Artery Stent: Preprocedural Planning (Distal Internal Carotid Diameter)

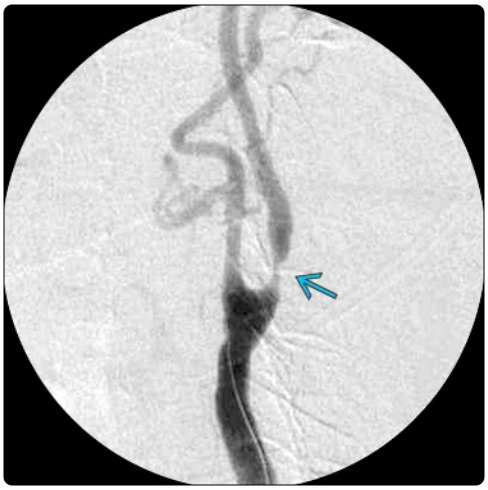


(Left) *Points can be plotted on the reformatted images from the same CTA using postprocessing software on a dedicated workstation. Calculations of the minimum and maximum diameters along the arterial course are made. The degree of stenosis is evaluated on this image.* **(Right)** *Precise measurements of arterial diameter are important for stent sizing. The normal distal ICA diameter impacts sizing of an embolic protection device, if used. The ICA diameter at the distal end of the stenosis is calculated here.*

Carotid Artery Stent: Preprocedural and Intraprocedural Comparison

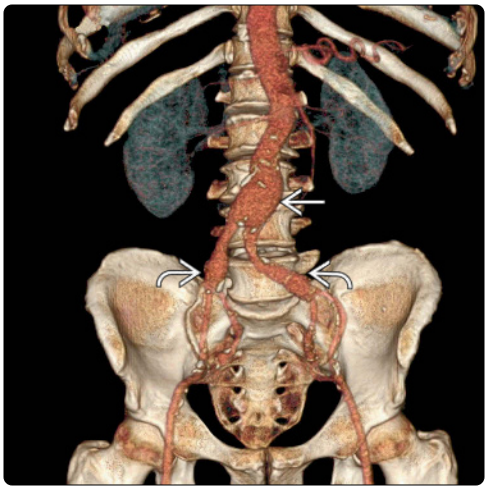


Carotid Artery Stent: Preprocedural and Intraprocedural Comparison

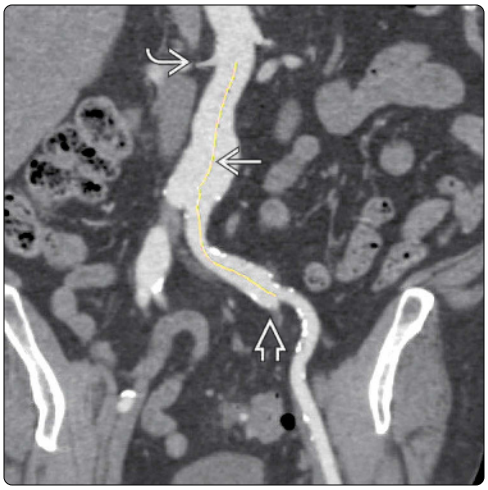


(Left) *The patient was being evaluated for possible carotid artery stenting because of a history of prior carotid endarterectomy and new onset of slurred speech. The CTA shows a severe left ICA stenosis.* **(Right)** *An intraoperative DSA correlates well with the preprocedural CTA and confirms the severe ICA stenosis. The CTA results indicated that the patient was anatomically suitable for carotid stenting with embolic protection.*

EVAR: Preprocedure Planning (Initial CTA Imaging Evaluation)

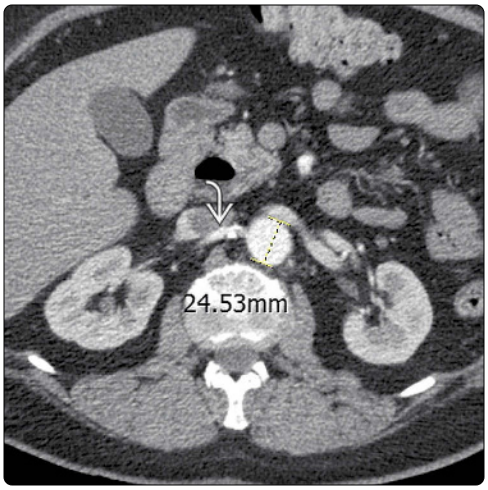


EVAR: Preprocedure Planning (Initial CTA Imaging Evaluation)

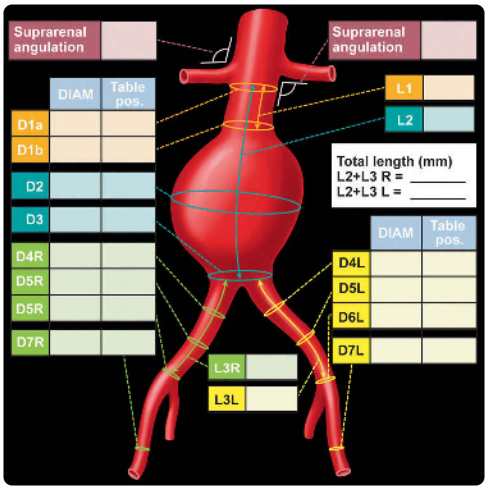


(Left) *3D reformation shows a satisfactory infrarenal neck length above an AAA. Both distal common iliac arteries are dilated. Careful preprocedural analysis of aortoiliac anatomy is critical to choosing an appropriate endograft for EVAR.* **(Right)** *A centerline has been plotted on the coronal MIP in the aortic and left common iliac artery lumina from the lowest renal artery to the iliac bifurcation. This is used to calculate endograft length and is usually more accurate than using axial table positions.*

EVAR: Preprocedure Planning (Proximal Neck Diameter Calculation)

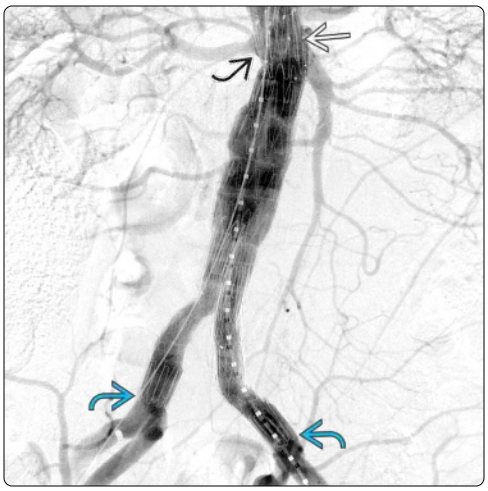


EVAR: Preprocedure Planning (Endograft Sizing Worksheet)

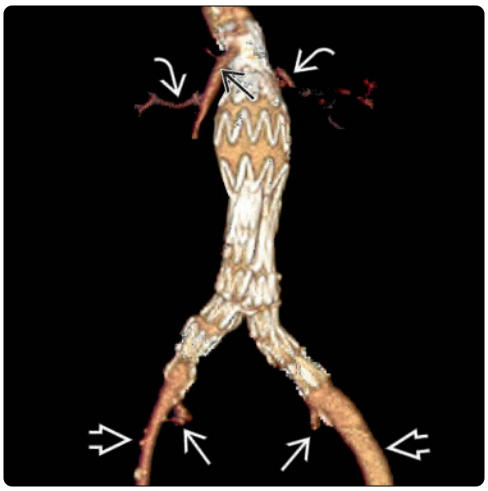


(Left) *Preprocedural axial CECT images are used to calculate diameters at multiple levels. In this image, the aortic neck diameter below the lowest renal artery is 24.5 mm diameter, evaluated over a 10-15 mm length (the optimal proximal seal zone length). Other important diameters include the aortic bifurcation and the common and external iliac arteries.* **(Right)** *A worksheet is used to plot vessel lengths and diameters from CTA image data. Appropriate endograft size and component lengths are then selected.*

EVAR: Intraoperative DSA Aortogram (Satisfactory Result)

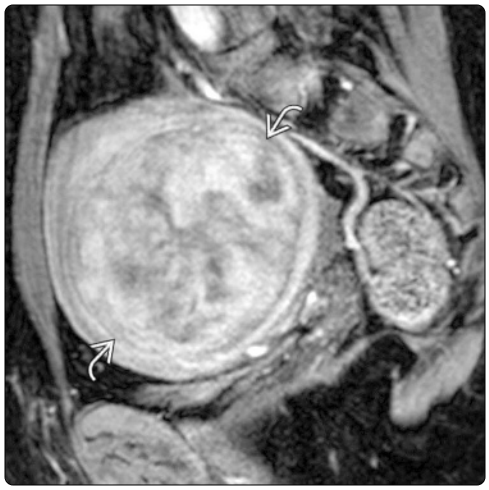


EVAR: Postprocedural Imaging Surveillance (3-Month Follow-Up)

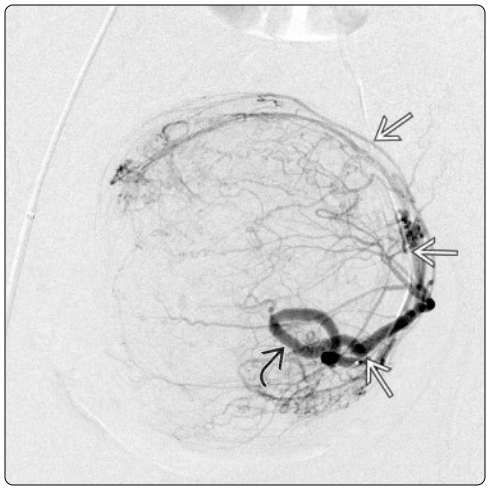


(Left) *DSA during EVAR shows an endograft extending from the lowest renal artery to both iliac bifurcations. The suprarenal endograft component consists of bare metal stents designed to aid in proximal fixation. Meticulous preoperative planning is critical to obtaining good EVAR outcomes.* **(Right)** *3D reformatted CTA 3 months after EVAR shows patency of the renal arteries, superior mesenteric artery, and both internal and external iliac arteries. Axial images showed a good endograft position and no endoleak.*

Uterine Artery Embolization: Preprocedural Planning (Sagittal MR)

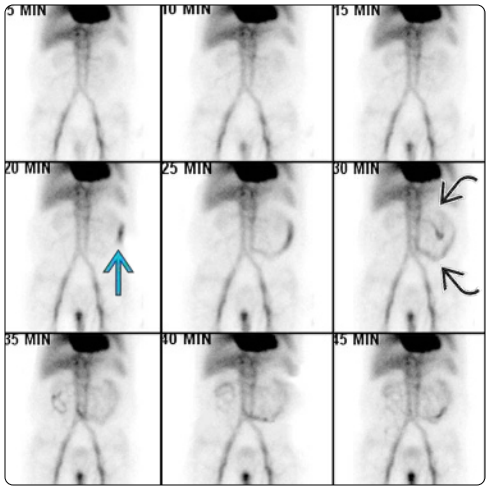


Uterine Artery Embolization: Intraprocedural DSA (Left Uterine Artery)

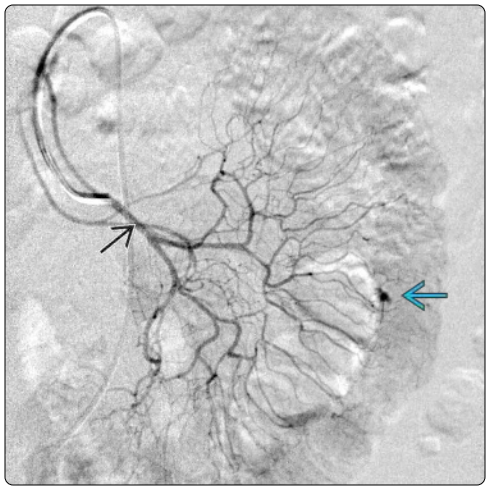


(Left) *Sagittal enhanced T1WI C+ MR in a patient with known uterine fibroids shows a large, heterogeneously enhancing fibroid. MR is the preferred modality for preuterine artery embolization evaluation, clearly demonstrating the size and location of fibroids as well as the degree of enhancement.* **(Right)** *Selective left uterine artery DSA via a coaxial microcatheter shows extensive vascularity, corresponding to the fibroid enhancement seen on MR. Embolization was performed from this catheter position.*

Acute Gastrointestinal Hemorrhage (Tc-99m-Labeled RBC Scintigraphy)

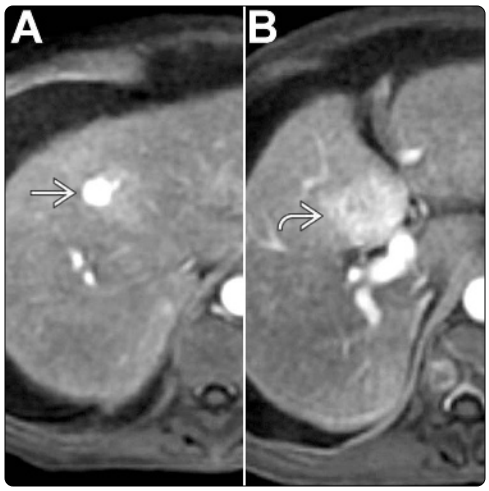


Acute Gastrointestinal Hemorrhage (Digital Subtraction Angiography)

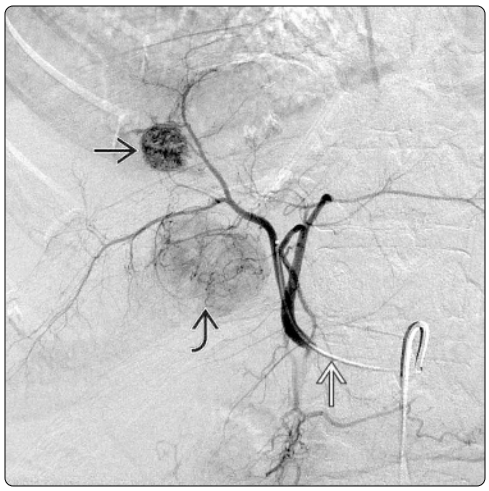


(Left) *Localizing GI bleeding can be difficult, particularly given its intermittent nature. Tc-99m-labeled red blood cell scintigraphy before DSA can determine if there is active bleeding and its location. Here, activity in the left abdomen accumulates in a small bowel distribution.* **(Right)** *As scintigraphy suggested, bleeding localized to a jejunal branch of SMA. Evaluation of celiac and IMA arteries was unnecessary, limiting contrast load and radiation dose during treatment.*

TACE of Hepatocellular Carcinoma: Preprocedural Evaluation (Initial MR)

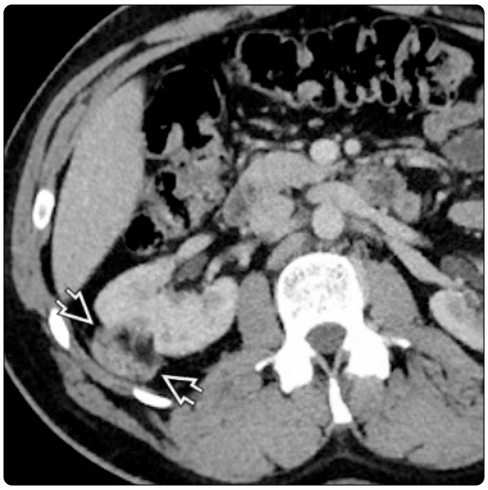


TACE of Hepatocellular Carcinoma: Intraprocedural (Preembolization DSA)

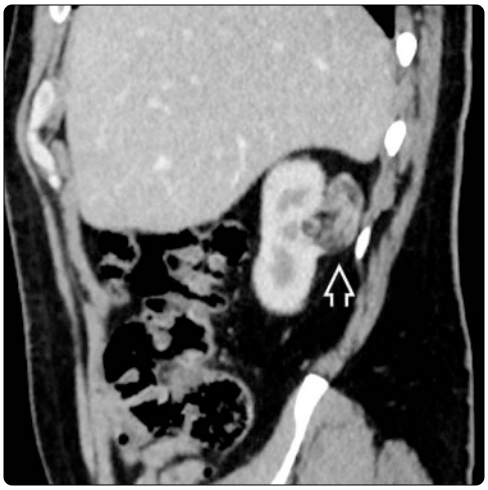


(Left) *(A) MR shows a 1.5-cm enhancing mass in segment VIII and (B) a 3.5-cm enhancing mass in segment V, consistent with hepatocellular carcinoma. Cross-sectional imaging with MR or CT assesses tumor number, location, and vascularity, plus vascular anatomy prior to TACE, and is more sensitive than intraprocedural DSA.* **(Right)** *Preprocedural imaging helps plan TACE as bilateral staged, lobar, or segmental. Here, a selective coaxial microcatheter confirms masses in segments VIII and V.*

Angiomyolipoma: Preprocedural Planning (Axial CECT)

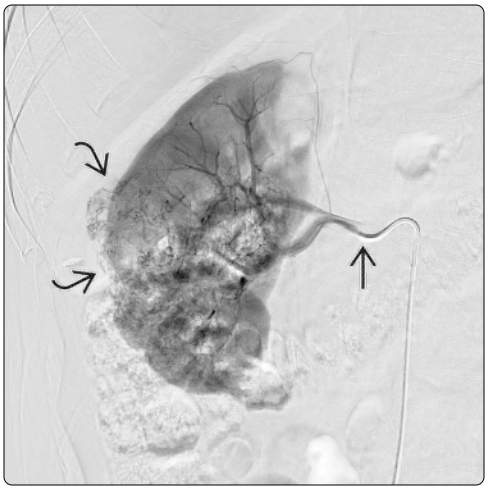


Angiomyolipoma: Preprocedural Planning (Sagittal CECT)

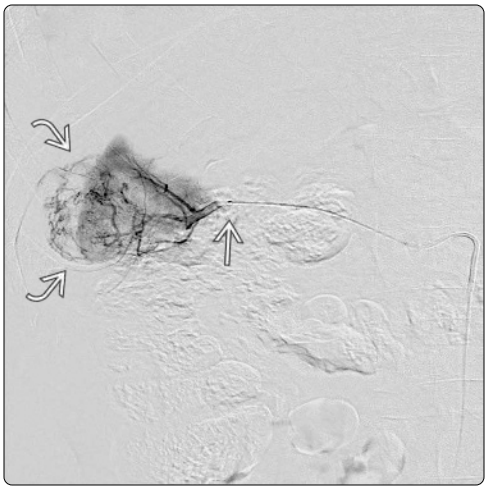


(Left) *Axial CECT demonstrates an exophytic, enhancing, fat-containing mass involving the right kidney representative of an angiomyolipoma.* **(Right)** *Sagittal CECT confirms the exophytic nature of the right renal angiomyolipoma. Preprocedural imaging suggests that, due to the location of the mass, a partial nephrectomy may be challenging. Alternatively, no barriers to endovascular embolization are apparent.*

Angiomyolipoma: Procedural Embolization (Renal Arteriogram)

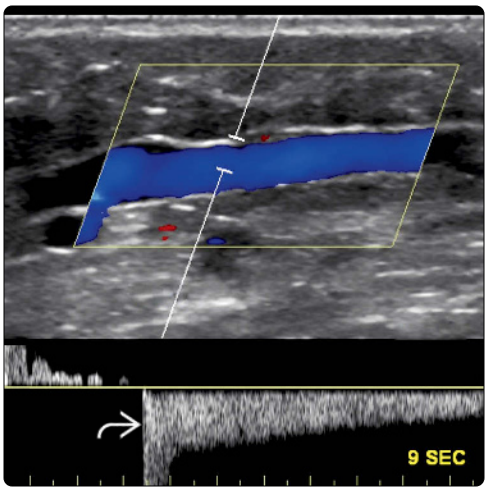


Angiomyolipoma: Procedural Embolization (Superselective Angiogram)

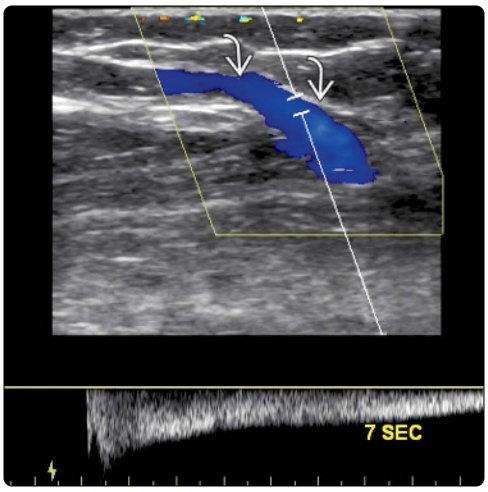


(Left) *A nonselective right renal arteriogram demonstrates arterial blush and neovascularity associated with the exophytic angiomyolipoma.* **(Right)** *A coaxial microcatheter was advanced until this super-selective right renal arteriogram demonstrated arterial blush of the angiomyolipoma, correlating well with the preprocedure CT. Particle embolization from this location treated the angiomyolipoma and minimized injury to uninvolved kidney.*

Endovenous Thermal Ablation (Doppler Evaluation for Reflux)



Endovenous Thermal Ablation (Doppler Evaluation for Reflux)



(Left) *Ultrasound mapping of the deep and superficial veins of the lower extremities and color Doppler evaluation of venous reflux are mandatory prior to thermal ablation of varicose veins. This case demonstrates 9 seconds of reflux in the left great saphenous vein, indicating the presence of venous insufficiency.* **(Right)** *Color Doppler US shows a large, refluxing superficial varix located within the posterior thigh. Preprocedure duplex ultrasound should include evaluation for incompetent perforators as well.*

KEY FACTS

PREPROCEDURE WORK-UP

- Review pertinent medical history, imaging, labs, indication for procedure
- Risk stratify for cardiac events, contrast-induced nephropathy, complications of sedation
  - Take appropriate steps (e.g., cardiology consult, pre and postprocedure hydration, anesthesia support)

INFORMED CONSENT

- Communication process between patient/patient's representative to authorize intervention
- Components include nature of procedure (purpose, risks, and benefits), alternatives, patient understanding, and voluntary acceptance
- Exception: Presumed consent in life-/limb-threatening emergency, no surrogate

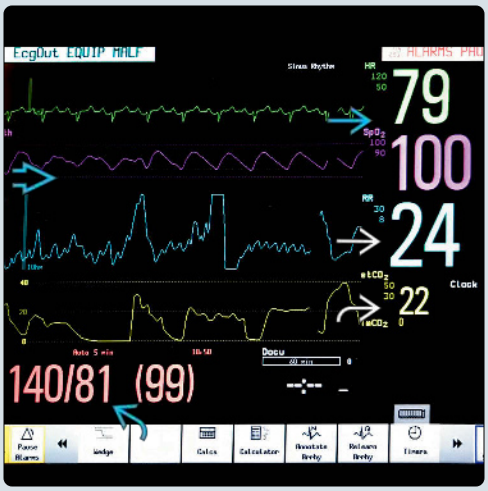
SEDATION

- Choose desired sedation level based on patient factors, operator preference, patient preference, and procedural complexity
- Moderate sedation most often used
  - Typically combination of benzodiazepine (Versed) and opioid (fentanyl)
  - Opioid reversal with naloxone; benzodiazepine reversal with flumazenil

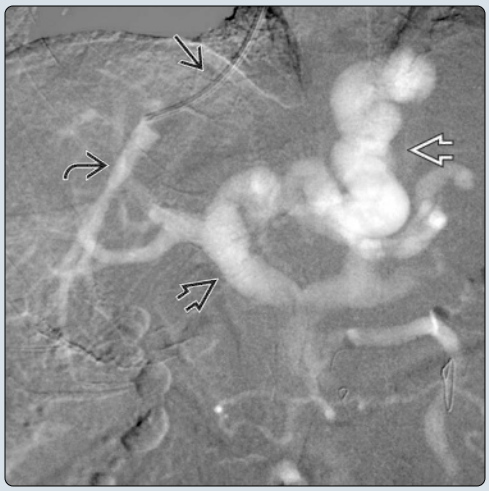
TIME OUT

- Ensure right patient, right procedure, correct side/site, signed informed consent
- Review relevant labs, history, need for antibiotics, special equipment

Vital Signs: Continuous Monitoring

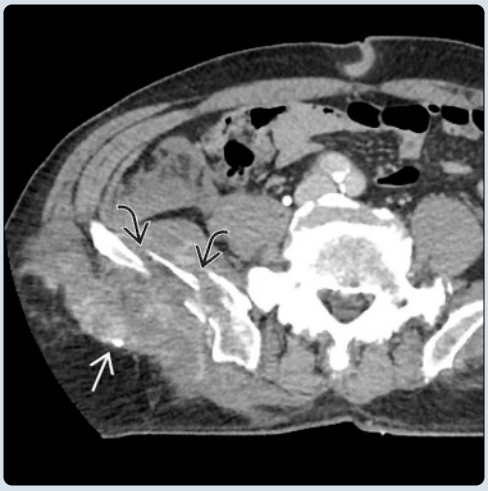


Alternative Contrast Agents: CO2

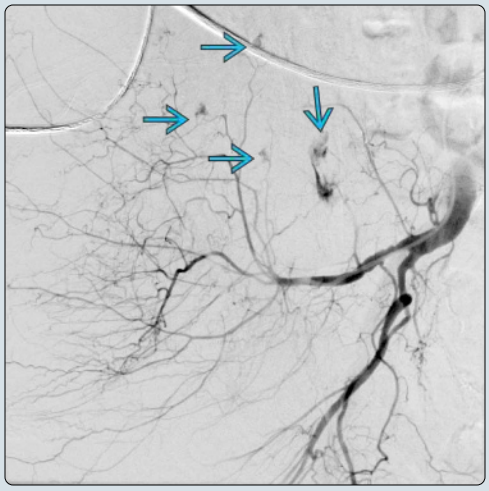


(Left) *Procedure with moderate sedation is shown. Pulse and oxygen saturation are continuously monitored. Blood pressure is taken every 5 minutes. End-tidal CO_2 and respiratory rate can also be monitored. This patient was hyperventilating. (Normal $etCO_2$ 35-45, RR < 20.)* **(Right)** *CO_2 contrast is an alternative for patients unable to receive iodinated contrast. Here, CO_2 injection via a catheter in the hepatic vein opacifies the portal vein and esophageal varices during TIPS.*

Pre-Procedural Planning & Imaging



Procedural Angiogram: Correlates with CT



(Left) *Axial CECT shows a patient who sustained significant trauma after being stuck by a car. Insignificant comminuted pelvic fractures are present as is evidence of contrast extravasation. Patient had concomitant head injuries and was intubated. No next of kin was available. Presumed consent was invoked to proceed with pelvic angiogram and embolization.* **(Right)** *A right internal iliac angiogram shows multifocal areas of extravasation. These were treated with gelfoam embolization. Patient was ASA class V-E*

PREPROCEDURE WORK-UP

Cardiac Risk Stratification

- Revised Cardiac Risk Index
  - Point given for each of the following
    - High-risk procedure
    - Ischemic heart disease
      - History of myocardial infarction, angina, abnormal stress test, pathologic Q waves
    - Congestive heart failure
    - History of cerebrovascular disease
    - Insulin-dependent diabetes
    - CKD with GFR > 2 mg/dL
  - Cardiac adverse event rate
    - 0 points: 0.4%
    - 1 point: 1%
    - 2 points: 7%
    - ≥ 3 points: 11%

Contrast-Induced Nephropathy Risk Stratification

- Definition: Increase in serum creatinine by 25% from baseline within 72 hours of contrast administration
- Natural course
  - Typically transient increase in serum creatinine
    - Peaks at 4-7 days
  - < 1% will progress to ESRD/need dialysis
- Scoring system
  - Hypotension or intraaortic balloon pump use = 5 points
  - Congestive heart failure = 5 points
  - Elevated baseline kidney function (serum creatinine > 1.5 mg/dL) = 4 points
  - > 75 years of age = 4 points
  - Anemia = 3 points
  - Diabetes mellitus = 3 points
  - Contrast volume = 1 point for each 100 mL used
- Prevention
  - Hydration
    - Elective outpatient: Oral hydration 12-24 hours before and after procedure
    - Elective inpatient: 1 mL/kg/h x 12 hours before and 12 hours after contrast administration

Preprocedure Performance Status

- Correlated with overall patient prognosis and postprocedure outcome
- Eastern Cooperative Oncology Group (ECOG) commonly used scales for cancer patients
  - Score between 0 (fully active) and 5 (dead)
- Commonly used scales for patients with liver disease
  - Model For End-Stage Liver Disease (MELD) score
    - MELD = 3.78×ln[serum bilirubin (mg/dL)] + 6.43 + 11.2×ln[INR] + 9.57×ln[serum creatinine (mg/dL)]
    - Originally used to predict outcome after TIPS
    - Prognostic indicator in chronic liver disease
    - 3-month mortality
      - > 40 ~ 70% mortality
      - 30-39 ~ 50% mortality
      - 20-29 ~ 20% mortality
      - 10-19 ~ 5.0% mortality
      - < 9 ~ 2% mortality
    - Also applied as objective tool in assigning need for liver transplant
  - Child-Pugh score
    - Based on grade of hepatic encephalopathy, severity of ascites and values of INR, albumin, and total bilirubin
    - Predictive of 1-year survival
      - A: 100%; B: !00%; C: 45%
    - Incorporated in triage of treatment for patients with HCC in Barcelona Clinic Liver Cancer (BCLC) staging

SEDATION

Level of Sedation

- Base sedation plan on procedural complexity & patient
- Sedation levels (in order of decreasing sedation)
  - General endotracheal anesthesia
  - Monitored anesthesia care
  - Deep sedation
  - Moderate sedation
  - Minimal sedation/anxiolysis
  - Local anesthesia only

Moderate Sedation

- Most often employed sedation plan/level for routine IR procedures
- Definition: Sedation state allowing patient to retain ability to respond purposefully to verbal/tactile stimuli
  - Cardiovascular function, respiratory function, and airway maintained
- Typical agents: Benzodiazepine (e.g., midazolam) + opioid (e.g., fentanyl)
  - Act synergistically
- Benzodiazepine
  - Actions: Anxiolysis, antegrade amnesia, sedative, muscle relaxation
  - Enhances effect of gamma-aminobutyric acid (GABA)
    - Reduces neuronal excitability
- Midazolam (a.k.a. Versed) preferred benzodiazepine
  - Typical adult midazolam dose
    - 0.5-2 mg initial bolus
    - 0.5-1 mg additional doses as needed
    - Use lower doses in debilitated patients, elderly patients, patients with respiratory insufficiency, hepatic impairment, renal failure
      - Single dose: Metabolism unchanged with renal failure
      - Multiple doses: Prolonged procedure increases duration of effect due to byproduct accumulation
      - Hepatic impairment → decreased clearance with stronger and prolonged effects
  - Pharmacokinetics
    - Metabolized by liver, excreted in urine
    - Onset of action: 2-5 minutes after IV injection
      - Wait 5 minutes before redosing
    - Elimination half life: 1.5-2.5 hours
      - Prolonged in elderly, obese, chronically ill, patients with CHF, patients with liver impairment, patients with renal impairment
    - Obesity: Systemic clearance of midazolam unchanged
  - Paradoxical reaction

  - Agitation, involuntary movements, hyperactivity, hostility, excitement
    - Seen in children, elderly, patients with dementia
  - Pregnancy class D
    - Excreted in breast milk
  - Reverse with flumazenil
    - Dose: 0.2 mg
      - Repeat q 45 seconds; can repeat 3x
    - Action: Competitive inhibition at benzodiazepine binding site on GABAA receptor
    - Biological half life: 15-30 minutes
      - Redosing may be necessary to avoid resedation
    - Lowers seizure threshold, may cause agitation
- Opioid
  - Action: Analgesia
    - μ opioid receptor agonist
  - Side effects/adverse reactions
    - Confusion, somnolence, constipation, nausea, hypoventilation/apnea, chest wall rigidity (especially in pediatric patients), bradycardia, itching, nausea
- Fentanyl (a.k.a. Sublimaze) preferred opioid
- Typical adult fentanyl dose
  - 25-50 μg initial bolus
  - 25-50 μg additional doses as needed
    - Highly potent (50-100x stronger than morphine)
    - Wide therapeutic index
- Pharmacokinetics
  - Onset: Immediate to 5 minutes
  - Biological half life: 10-20 minutes
  - Metabolized in liver
    - Hydrolysis of esters
    - Cirrhosis/hepatic failure does not affect pharmacokinetics
    - Decreased hepatic blood flow affects metabolism more than hepatic failure/cirrhosis
  - Excreted in urine and feces: No active metabolites, no need for dose reduction in renal failure
  - Lipophilic: Increased volume of distribution in obese patients with prolonged effects
- Pregnancy class C
  - Does enter breast milk
- Naloxone duration < fentanyl; monitor for resedation
- Opioid antagonist: Naloxone 0.4 mg q 4 minutes
- Presedation checklist
  - Allergies, medications, cardiovascular issues
    - Ejection fraction (EF) < 30%: Consider anesthesiology

Presedation Checklist

- NPO status (institution specific)
- Risk factors for potential adverse events
  - Mallampati Score 3 or 4
    - Class 1: Soft palate and uvula completely visible
    - Class 2: Uvula completely visible
    - Class 3: Only base of uvula visible
    - Class 4: No part of uvula visible
  - Facial dysmorphism (micrognathia), facial trauma, obesity
  - Hx of continuous positive airway pressure (CPAP) dependent sleep apnea
  - Problems with prior sedation
  - EF < 30%
  - ASA score IV or V
- 0.5% adverse cardiopulmonary events from moderate sedation
  - Proper patient selection and early recognition and appropriate intervention avoids complications

IODINATED CONTRAST REACTIONS

Prophylaxis Regimens

- For patients with history of mild/moderate reactions
  - Aim to prevent progression to severe reactions
  - May still have mild reactions
- 13-hour prep (preferred)
  - Prednisone 50 mg PO at 13, 7, & 1 hours prior and diphenhydramine 50 mg (PO/IV/IM) 1 hour prior to contrast administration
- 1-hour prep (for emergencies)
  - Methylprednisolone 40 mg IV and diphenhydramine 50 mg (PO/IV/IM) 1 hour prior to contrast administration

Treatment of Reactions

- Hives
  - PO/IV diphenhydramine 25-50 mg ± IM epinephrine (1:1,000) 0.1-0.3 mg
- Facial/laryngeal edema
  - O_2 6-10 L/min (via facemask)
  - IM epinephrine (1:1,000) 0.1-0.3 mg
  - If significant, call code blue for anesthesia back-up and possible intubation
- Bronchospasm
  - O_2 6-10 L/min (via facemask)
  - IM epinephrine (1:1,000) 0.1-0.3 mg
  - Albuterol nebulizer
  - If falling O_2 saturation, increased work of breathing or lack of response to tx, call code blue
- Hypotension with tachycardia
  - Elevate legs
  - Bolus 500-1,000 mL normal saline
  - O_2 6-10 L/min (via facemask)
  - Consider IM epinephrine (1:1,000) 0.1-0.3 mg
    - Alternatively IV epinephrine (1:10,000) 0.1 mg
- Hypotension with bradycardia
  - Elevate legs
  - Bolus 500-1,000 mL normal saline
  - O_2 6-10 L/min (via facemask)
  - IV atropine 0.6-1 mg

CO_2 Contrast

- Advantages: Not allergenic, not nephrotoxic, inexpensive, may use unlimited amounts
  - Wait 2 minutes between injections to allow for expulsion by lungs
- Disadvantages
  - Cannot be used above diaphragm
    - Risk of gas embolism to cerebral, coronary arteries and spinal cord
  - Vessel size underestimation
    - Dependent part of vessel not opacified
      - Posterior plaques/stenoses/pathology not depicted
  - Worser image quality

American Society of Anesthesiologists (ASA) Physical Status Classification System

Score	Description
ASA I	Normal, healthy patient
ASA II	Mild systemic disease (e.g., obesity with BMI 30-40, current smoker, well-controlled DM or HTN)
ASA III	Severe systemic disease (e.g., obesity with BMI > 40, ESRD on hemodialysis, alcohol dependence, poorly controlled DM or HTN)
ASA IV	Severe illness that is constant threat to life (e.g., recent stroke or MI, sepsis, severe reduction in ejection fraction)
ASA V	Moribund patient; not expected to survive without operation (e.g., ruptured AAA, massive trauma)
ASA VI	Brain-dead patient; organs being harvested

Addition of "E" denotes an emergency surgery; delay would cause increase in morbidity or mortality.

Aldrete Score

Activity	Respiration	Consciousness	Circulation	Color	Score
Moves all extremities voluntarily or on command	Breaths deeply, normally and coughs freely	Fully awake, alert	Blood pressure at or within 20% of preprocedure value	Normal	2
Moves 2 extremities voluntarily or on command	Dyspnea or shallow breathing	Arousable to voice	Blood pressure 20-50% of preprocedure value	Pale	1
Does not move	Apneic	Not responsive to voice or touch	Blood pressure > 50% different than preprocedure value	Cyanotic	0

Score for the measurement of recovery after anesthesia (post anesthesia), which includes activity, respiration, consciousness, blood circulation and color. Score ≥ 9 typically required prior to discharge.

Ead H: From Aldrete to PADSS: Reviewing discharge criteria after ambulatory surgery. J Perianesth Nurs. 21(4):259-67, 2006.

- Higher radiation used as faster filming rates needed
- Contraindications: Pulmonary hypertension, COPD, right-to-left shunt
- Complications
  - Vapor lock in heart
    - Trapping of CO_2 in right atrium preventing normal venous return
      - Causes bradycardia and hypotension
      - Occurs exclusively during venography
      - May reflect contamination with room air
    - Place patient into left lateral decubitus position
  - Vapor lock in mesenteric arteries
    - Can cause abdominal pain
    - More common in patients with AAA

MONITORING

Intraprocedural Monitoring

- Continuous oxygen saturation monitor
  - Pulse oximetry: Measures O_2 saturation in blood
    - Slow to indicate change in ventilation
      - Takes 1-2 minutes to show change
- Continuous ECG
  - Arrhythmia could signify malpositioned guidewire/catheter
- Blood pressure (q 5 minutes)
  - Hypotension and desaturation
    - DDx: Oversedation, pneumothorax
  - Hypotension and tachycardia
    - DDx: Active bleeding, infection
- Capnography: Carbon dioxide monitoring
  - Hypoventilation/hypercarbia precedes desaturation
    - Capnography: Noninvasive measurement of partial pressure of carbon dioxide in exhaled breath
      - Measure of ventilation
      - Provides rapid evaluation of patient condition
  - Normal $EtCO_2$ 35-45 mm Hg
    - > 45 = hypoventilation (oversedation)
    - < 35 = hyperventilation (anxiety/pain)

Postprocedure Monitoring/Discharge

- Recovery length and appropriateness of discharge depends on patient, procedure, procedure length, complications, dose of sedation and institution
  - Typical criteria
    - Modified Aldrete score of ≥ 9 or return to patient's baseline
    - Patient not suffering from nausea, vomiting, or significant pain
    - Patient accompanied by responsible adult
  - If reversal agent given, watch for resedation for 1.5 hours after reversal agent given
- No driving, operating heavy machinery, important decisions x 24 hours after sedation
- Amnesia can persist for hours after sedation; give written postprocedure instructions

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1. Rafiei P et al: Society of Interventional Radiology IR Pre-Procedure Patient Safety Checklist by the Safety and Health Committee. J Vasc Interv Radiol. 27(5):695-9, 2016

KEY FACTS

TERMINOLOGY

- Radiation risk is inversely related to patient age
- Sequela of radiation exposure is often delayed

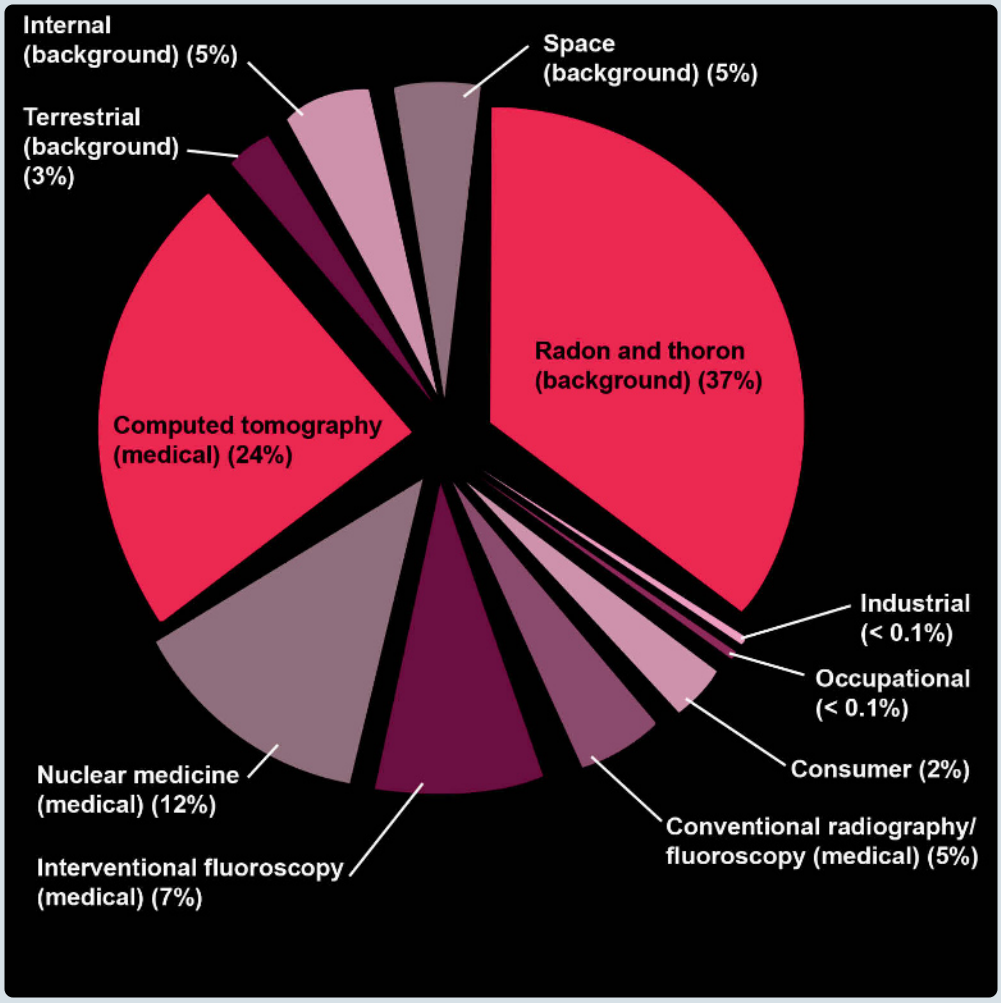
PREPROCEDURE

- Evaluate imaging to determine if procedure requires ionizing radiation
  - If ionizing radiation required, evaluate how to minimize dose
    - Dose reduction should not be done at sacrifice of procedural safety or efficacy
    - CT-guided procedures often do not require same image quality as diagnostic CT studies
  - Check if patient has already received significant radiation to procedural area
    - Repeated smaller, fractionated doses can also cause radiation injury

POST PROCEDURE

- Discuss with patient if exam required significant radiation dose (any of following)
  - Peak skin dose > 3 gray (Gy)
  - Reference point air kerma > 5 Gy
  - Kerma air product > 500 Gy·cm²
  - Fluoroscopy time > 60 minutes
- Advise patient on possible side effects
  - Explain that symptoms may not appear for weeks to months
- Plan appropriate follow-up

All Exposure Categories: Percentage of Collective Effective Dose (2006)



The largest source of collective effective dose to USA population as of 2006 was from radon and thoron background radiation at 37%. The largest contribution to medical radiation exposure was computed tomography at 24%, followed by nuclear medicine at 12%. Interventional fluoroscopy comprised 7% of total effective dose.

TERMINOLOGY

Definitions

- **As low as reasonably achievable (ALARA)**: Effort to maintain exposures to radiation as far below dose limits as is practical

Radiation Basics

- **Absorbed dose**: Amount of energy absorbed by matter
  - Measured in **gray (Gy)**, a Standard International (SI) unit
  - 1 Gy = 1 joule/kg
  - Radiation-absorbed dose (rad); outdated unit
    - 0.01 Gy = 1 rad
- **Equivalent dose**: Radiation dose weighting based on harmful biologic effect of dose
  - Measured in **sieverts (Sv)**, an SI unit
  - 1 Sv = 100 roentgen equivalent man **(rem)**, a non-SI unit
    - 1 rem increases chance of cancer by 0.055% over lifetime
    - Millirem (mrem): Often used to describe medical device dosage
- **Effective dose**: Equivalent dose accounting for tissue/organ sensitivity and specific damage from radiation
  - Measured in Sv (SI) or rem (non-SI)
- **Effects of ionizing radiation**
  - **Deterministic**
    - Effects exhibit threshold; below threshold, effect is not observed
    - Severity of effect increases with increasing dose above threshold (e.g., radiation-induced hair loss, skin injury, cataracts, sterility)
  - **Stochastic**
    - Probabilistic; nondeterministic health effects
    - Probability of event increases linearly with increasing dose without threshold, but severity of effect is constant (e.g., cancer)
  - **Biologic effect of radiation doses**
    - 10 Sv: High probability of death within days/weeks
    - 1 Sv: 5.5% ↑ probability of cancer during lifetime
    - 100 millisieverts (mSv): 0.5% probability of cancer during lifetime
    - Radiation risk is inversely related to patient age
    - Sequela of radiation exposure is often delayed, frequently weeks to months after exposure

PREPROCEDURE

Preprocedure Imaging

- Evaluate imaging to determine if procedure requires ionizing radiation
- If ionizing radiation required, evaluate best strategies and patient position to reduce dose

Getting Started

- **Factors affecting fluoroscopy dose**
  - Patient size
  - Peak kilovoltage (kVp), milliamps (mA), time
  - Distance from source
  - Image magnification and collimation
  - Beam angle: Perpendicular, oblique, lateral

PROCEDURE

Ways to Reduce Patient Dose in Fluoroscopy

- Optimize available resources
  - Utilize ultrasound guidance when possible/safe
  - Review prior imaging before starting case (limits repeat intraprocedural imaging)
  - Understand patient's prior surgical and medical history prior to starting case (limits unnecessary imaging in certain instances)
- Utilize pulse fluoroscopy
  - Lowest frame rate possible while maintaining procedure safety and efficacy
  - Lower frame rate = lower dose
- Last image hold rather than spot images
- Demagnify: Limit magnification
  - Magnification (geometric and electronic) generally increases dose
- Collimate beam: Limit visualization to area of interest
- Minimize fluoroscopy time
  - Do not fluoro while moving patient or C-arm
- Minimize use of digital subtraction angiography
  - Can use last image hold to document normal findings (e.g., femoral access site, patent hemodialysis access)
- Maximize source to patient difference (i.e., increase patient table height)
  - Dose is exponentially inversely related to distance from source
- Minimize distance from patient to detector
  - Moving detector 4 inches closer to patient = 17-29% dose reduction
- Remove unnecessary tissue within image field
  - Arms out of beam on lateral views
  - Oblique to get spine out of beam if possible
- Place leaded shields under/covering patient outside of area of interest
  - Circumferential shielding for pregnant patients
- Periodically adjust beam angle
  - Reduces dose to specific area of tissue; spreads dose over larger area of tissue

Ways to Reduce Operator Dose in Fluoroscopy

- Reduce patient dose: Reduces scatter to operator
  - Highest dose to proceduralists occurs via scatter
- Wear radiation protection equipment (e.g., leaded glasses, thyroid shield, vest, skirt)
- Maximize distance between operator and patient/source
  - Step out of room for power injections/DSA
  - Use extension tubing for hand injections
  - Optimize location of source, patient, monitors, and equipment to maintain maximum operator distance
    - Some procedures (e.g., hemodialysis access declot, vertebroplasty, left-sided biliary access) require operator to stand quite close, even minimally increased distance achieved can result in significant operator dose reduction
- Radiation shields
  - Ceiling-mounted mobile shield
  - Rolling mobile shields
  - Under-table shields

Annual Occupational Dose Limits

	Standard International (SI) Units	Non-SI Units
Total effective dose (whole body)	50 mSv	5 rem
Lens	150 mSv	15 rem
Skin, organ, extremity	500 mSv	50 rem
Total effective dose (fetus)	5 mSv	0.5 rem

Tissue Reactions to Acute Radiation Exposures

Dose	Expected Reactions
< 2 gray (Gy)	Cataract formation, marrow suppression, cognitive impairment
2 Gy	Transient skin erythema, cataract formation
3 Gy	Temporary hair loss, permanent sterility (testes)
4 Gy	Temporary hair loss
5 Gy	Prolonged skin erythema, partial permanent hair loss
6 Gy	Permanent sterility (ovaries), pneumonitis
7 Gy	Permanent hair loss, renal failure
10 Gy	Prolonged skin erythema, skin atrophy, telangiectasia
15 Gy	Skin necrosis

Note: Many reactions are not acute and may take weeks to months to develop.

- Angle detector toward operator when doing oblique or lateral imaging (i.e., radiation source further from operator)
  - Reduces scatter to operator
  - More patient scatter occurs toward source
- Wear radiation monitoring badges (whole body, ring)
  - Review quarterly dose reports; anticipate results based on work performed, recognize unexpected results
- Exclude hands from fluoroscopy beam
  - Angle fluoroscopy source and detector
  - Intermittently visualize between maneuvers requiring hands within field
  - Collimate tightly when hands near beam
  - Hold procedural equipment in place with hemostats or towels when visualizing

Ways to Reduce Patient Dose in CT

- Reduce kVp
  - kVp of 100 is good initial level
  - May require increase in mA but overall dose decrease
- Increase pitch
- Minimize number of scans
- Minimize field of view
- Limit localizing/scout images

Pregnant Patient Guidelines

- Emergent: Use ionizing radiation if clinically appropriate
- Nonemergent: Optimize ultrasound/MR before CT/fluoroscopy
  - Left flank pain: Consider ultrasound evaluation for hydronephrosis
  - Left lower quadrant pain: Consider ultrasound evaluation for ovarian torsion
  - Right lower quadrant pain
    - < 31 weeks pregnant, consider ultrasound
    - > 31 weeks pregnant, consider MR
- If planned dose > 10 mGy, consider advice of medical physicist
- If delivered dose > 50 mGy, case will likely require review by medical physicist
  - Pulmonary embolism protocol CT can deliver 20 mGy to each breast
    - 2-view mammogram typically delivers 3 mGy

POST PROCEDURE

Expected Outcome

- Risk of appropriate, limited medical imaging
  - Inconclusive epidemiological data
  - Linear no-threshold model currently used may be overly conservative
  - Medical imaging typically performed in older, selective population
- Relative risk of appropriate, limited medical imaging
  - Hard to define since lifetime risk of cancer is relatively high (as high as 42%) even without medical imaging

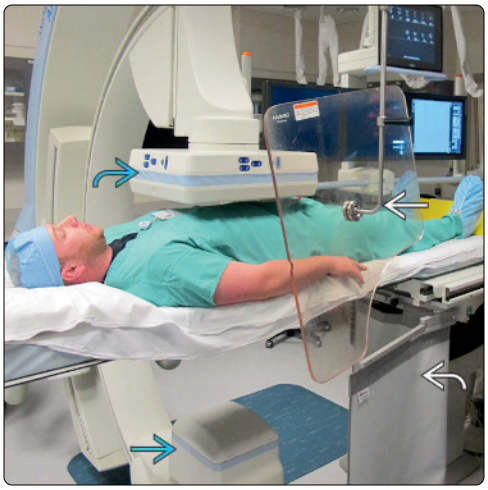
Things To Do

- Discuss with patient when exam performed required significant radiation dose
  - Advise patient on possible side effects
  - Plan appropriate follow-up

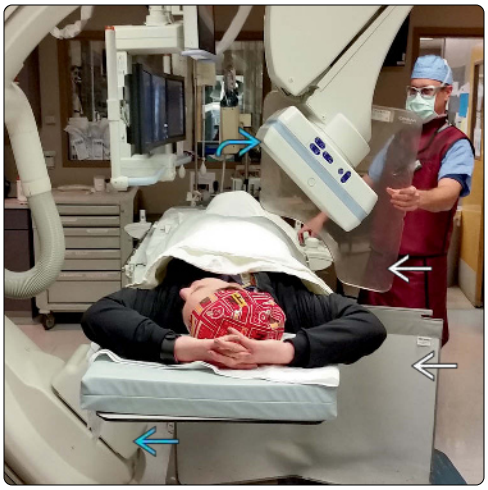
SELECTED REFERENCES

1. United States Nuclear Regulatory Commission. NRC Regulations (10 CFR). Part 20: Standards for protection against radiation. Published June 31, 2015
2. Authors on behalf of ICRP et al: ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs–threshold doses for tissue reactions in a radiation protection context. Ann ICRP. 41(1-2):1-322, 2012

Dose Reduction: Patient and Operator

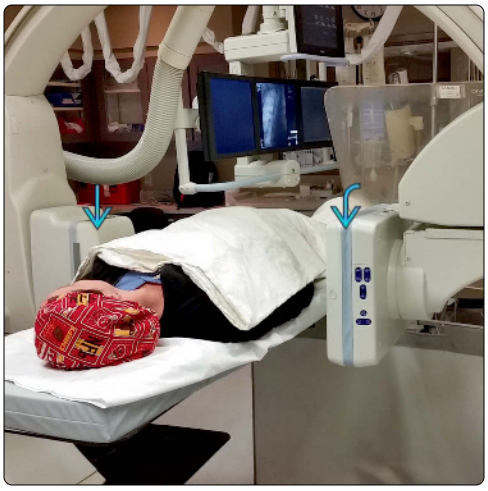


Dose Reduction: Oblique and Lateral

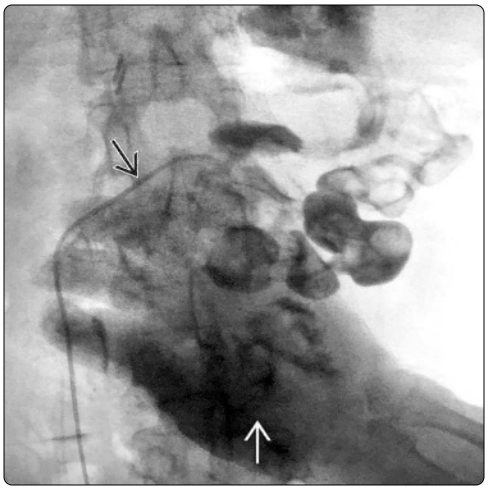


(Left) *The patient is elevated away from the radiation source, as close to the detector as possible. Ceiling-mounted and table-mounted mobile shields are in position.* **(Right)** *During oblique or lateral imaging, the radiation source should be directed away (and the detector toward) the operator if possible, decreasing operator exposure to scatter radiation. Mobile shields are in use, and the operator has a light-weight protective vest, skirt, thyroid, and eyewear shielding.*

Suboptimal: Lateral Dose

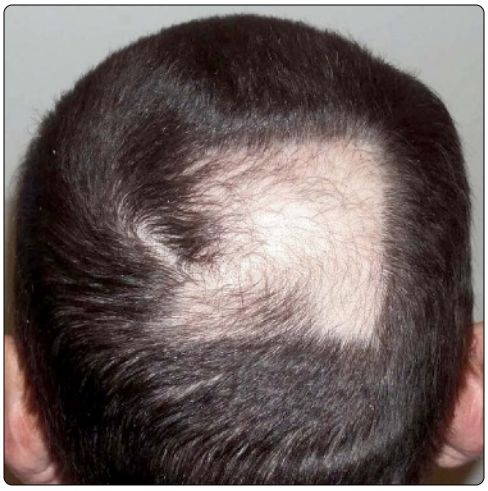


Suboptimal: Operator's Hand in Field

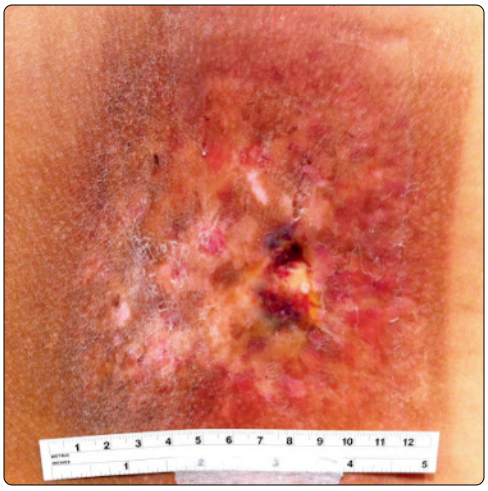


(Left) *The patient's arms are within the path of the radiation, unnecessarily increasing the amount of tissue imaged and thus the dose produced. Additionally, the patient is closer to the source than to the detector, again increasing dose.* **(Right)** *The operator's hand could be excluded from this sinogram by angling the fluoroscopy beam and increasing collimation, using hemostats or towels to hold the catheter in place, or imaging between contrast injections. The operator should consider using a ring monitor.*

Radiation-Induced Temporary Hair Loss



Radiation-Induced Skin Injury



(Left) *This patient experienced temporary hair loss due to radiation from a neurointerventional procedure. This typically occurs with an acute skin dose of 3-4 gray.* **(Right)** *Severe skin erythema and focal necrosis occurred in this patient following a complex transjugular intrahepatic portosystemic shunt (TIPS) procedure. This photograph was obtained ~ 6 months after the TIPS. Two years after the procedure, the skin has healed, but a large scar remains.*

Medications

KEY FACTS

PREPROCEDURE

- Reliable IV access almost always desired before beginning procedure
  - Allows for rapid and reliable delivery of medications
- Label all medications in procedural field
  - Color-coding syringes may also limit medication perfusion

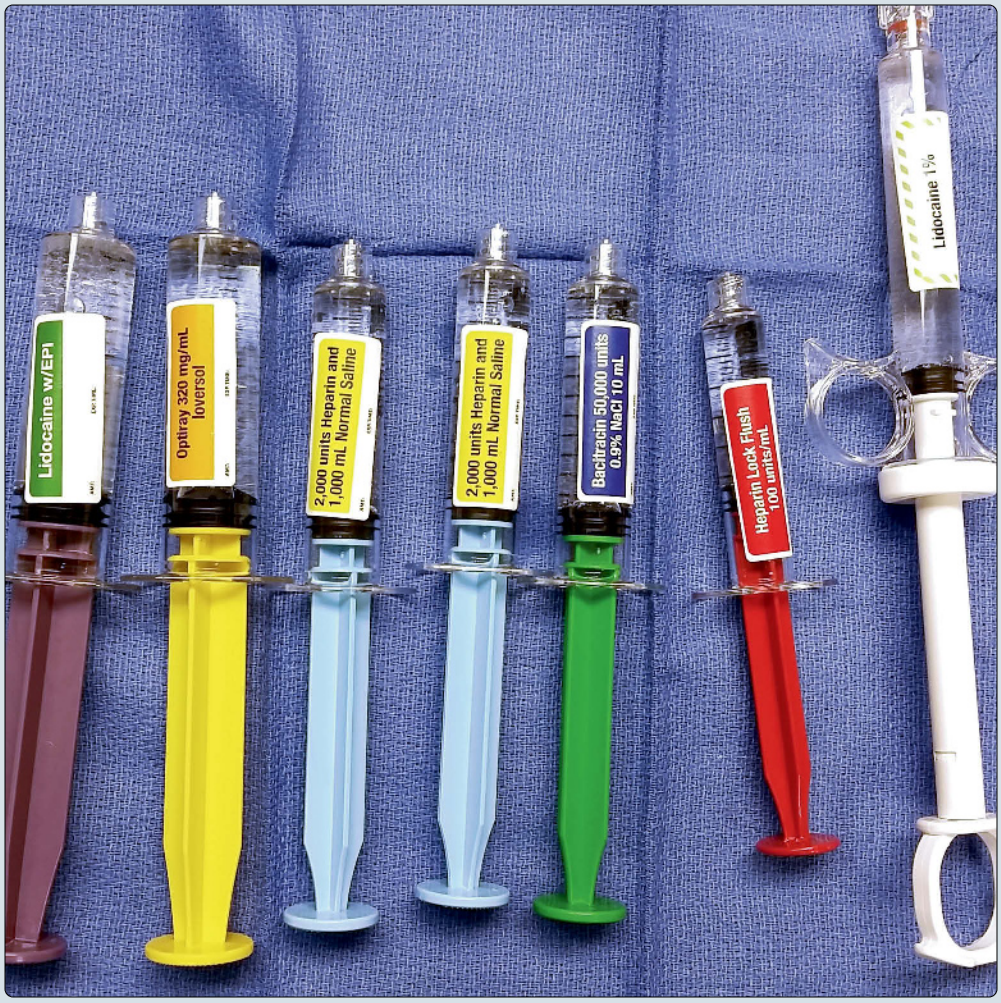
PROCEDURE

- Perform "time-out" prior to procedure
  - Confirm patient allergies
  - Provide pretreatment for contrast allergies
- Use closed-loop communication with staff to verify medications
- If medication not having expected effect, check IV tubing
  - Tubing may be disconnected, kinked, or occluded
  - IV may be infiltrating to subcutaneous tissue
  - Giving additional doses without checking tubing can result in overdosing medications
- Be prepared to treat allergic reactions to contrast or medications
- Have reversal medications available

POST PROCEDURE

- Document any new contrast or medication allergies
  - Update patient's medical record
- Monitor patients receiving sedation or analgesia
- Explain postprocedure medications to patients and their support individual(s)

Medications and Color-Coded Syringes



All medications on the sterile field are appropriately labeled. Color-coded syringes may also be used to decrease the chance of medication confusion and error.

PREPROCEDURE

Analgesia/Pain Management

- Opioids
  - Secondary effects can produce sedation
  - Monitor for respiratory depression
  - **Opioid reversal agent: Naloxone (Narcan)**
    - Typical dose 0.1-0.2 mg IV every 2-3 min
  - Fentanyl (Sublimaze): Opioid
    - Most common for interventional procedures
    - Rapid onset (within min), lasts 30-60 min
    - Typical initial dose 25-100 µg, redose as needed
  - Hydrocodone: Opioid
    - Typical dose: 5-10 mg
  - Hydromorphone (Dilaudid): Powerful opioid
    - Typical dose: 0.5-2.0 mg IV or 2-4 mg PO
  - Morphine: Opioid
    - Typical dose: 2-10 mg IV
  - Oxycodone (Roxicodone): Opioid
    - Typical dose: 5 mg PO
  - Tramadol (Ultram): Opioid for moderate pain
    - Typical dose: 50-100 mg
- Ketorolac (Toradol): Powerful NSAID
  - Typical dose: 15 mg IV q 6 hr or 10 mg PO q 4-6 hr
  - Caution in patients with renal dysfunction
  - Meperidine (Demerol): Opioid
    - Used to treat rigors
    - Typical dose: 50-150 mg IM or 25-50 mg IV

Antibiotics

- Ampicillin (Omnipen): Broad-spectrum aminopenicillin
  - Typical dose: 250-500 mg PO q 6 hr or 1-2 g IV q 4-6 hr
- Ampicillin/sulbactam (Unasyn): β-lactamase inhibitor
  - Typical dose: 1.5-3 g IV q 6 hr
- Bacitracin: Concentration of 5,000-10,000 units/mL may be flushed in port pockets or central venous catheter tunnels
- Cefazolin (Ancef): 1st-generation cephalosporin
  - Typical dose: 1-2 g IV within 1 hr of procedure
- Cefotetan (Cefotan): 2nd-generation cephalosporin
  - Typical dose: 1-2 g IV
- Cefoxitin (Mefoxin): 2nd-generation cephalosporin
  - Typical dose: 1-2 g IV
- Ceftriaxone (Rocephin): 3rd-generation cephalosporin
  - Typical dose: 1 g IV
- Ciprofloxacin (Cipro): Fluoroquinolone
  - Typical dose: 250-500 mg PO 2x daily x 5-7 days
- Clindamycin (Cleocin): Lincosamide
  - Typical dose: 600-900 mg PO or IV
  - **Alternative for patients allergic to penicillins**
- Gentamicin (Garamycin): Aminoglycoside
  - Typical dose: 1.5 mg/kg IV
  - Usually given in combination with ampicillin
    - May be given with vancomycin or clindamycin in patients allergic to penicillins
- Levofloxacin (Levaquin): Fluoroquinolone
  - Typical dose: 250-750 mg PO or IV daily
- Metronidazole (Flagyl): Nitroimidazole
  - Typical loading dose: 1 g or 15 mg/kg IV
  - Typical maintenance dose: 500 mg or 7.5 mg/kg IV or PO
- Piperacillin/tazobactam (Zosyn): Broad-spectrum penicillin with β-lactamase inhibitor
  - Typical dose 3.375 g IV
- Vancomycin (Vancocin): Glycopeptide
  - Typical dose 1 g or 15 mg/kg IV
  - **Alternative for patients allergic to penicillins**

Anticoagulant/Antiplatelet

- Clopidogrel (Plavix): Thienopyridine platelet inhibitor
  - 300 mg PO loading dose on day of stent placement
  - 75 mg PO daily following stent placement
- Enoxaparin (Lovenox)
  - Low molecular weight heparin
  - Typical dose: 40 mg subQ daily for deep vein thrombosis (DVT) prophylaxis
  - 1 mg/kg subQ 2x daily for DVT treatment
- Heparin
  - Intraprocedural dose
    - Weight-based nomogram: 80 units/kg body weight
    - Standard-care nomogram: 5,000 units IV
    - Decreased in cases of elevated prothrombin time, warfarin, or low patient weight
  - Continuous infusion
    - Weight-based nomogram: 80 units/kg body weight bolus, 18 units/kg/hr IV infusion
    - Standard-care nomogram: 5,000 units IV bolus, 800-1,600 units/hr IV infusion
    - Titrate to partial prothrombin time level of 1.5-2.5 x normal
    - Immediate onset, lasts 60-90 min
  - Monitor for heparin-induced thrombocytopenia (HIT)
  - Reversed with protamine sulfate
    - Typical dose 10 mg/1,000 units heparin, decreased based on time since last heparin administration
- Locking of central venous catheters
  - Can still cause systemic anticoagulant or allergic effects
  - Fill volume of each lumen
    - Heparin 1,000 units/mL: Can cause HIT
    - Tissue plasminogen activator: ~ 2 mg
    - Sodium citrate 4%
- Tissue plasminogen activator (Alteplase)
  - Typical dose: 0.5-1.0 mg/hr, catheter directed thrombolysis
  - Typical dose: Up to 10 mg laced into thrombus for pharmacomechanical thrombolysis
- Warfarin (Coumadin)
  - Typical initial dose: 2-5 mg daily x 1-2 days
  - Titrate dose to international normalized ratio (INR) goal, typically 2-3 for DVT &/or PE
  - Effect lasts ~ 5 days

Anxiolysis/Sedation

- Benzodiazepines
  - Monitor for respiratory depression
  - **Benzodiazepine reversal agent: Flumazenil**
    - Flumazenil (Romazicon)
      - Typical dose: 0.2 mg IV, repeated every minute as needed; maximum dose: 1 mg
  - Lorazepam (Ativan): Benzodiazepine
    - Typical dose 0.5-2.0 mg IV or PO
    - 2-4 mg IV for seizures/status epilepticus

- Midazolam (Versed): Benzodiazepine
  - Most common medication used for sedation
  - Ensure adequate NPO status, typically 6-8 hr
  - Onset 2-4 min, lasts 45-60 min
  - Typically dosed in 0.5-1.0 mg IV boluses
  - May also give 1 mg IV for seizures
- Diphenhydramine (Benadryl): Antihistamine
  - Typical dose: 25-50 mg IV or PO

Blood Glucose Management

- Hyperglycemic management
  - Insulin: Typical dose: 5-10 units subcutaneous
    - Treatment dose variable
- Hypoglycemia management
  - Dextrose
    - Typical dose: 25 g (50 mL) of 50% dextrose (D50W) IV
    - Can also order 15-g tablets or 4 oz juice PO
  - Glucagon: Typical dose 1 mg IV, IM, or SubQ

Blood Pressure Management

- Acute antihypertensives
  - Clonidine (Catapres): Antiadrenergic
    - Typical dose: 0.1-0.2 mg PO, can repeat hourly
    - Max dose: 0.7 mg
  - Hydralazine: Vasodilator
    - Typical dose: 10-20 mg IV; onset 10-20 min
    - 10- to 80-min duration, repeat as needed
    - May increase heart rate
  - Labetalol (Trandate): Nonselective β-blocker
    - Typical dose: 20 mg IV; onset 5 (peak 10-15) min
    - Caution with COPD/asthma
    - Lowers heart rate
  - Metoprolol (Lopressor): β1-blocker
    - Typical dose: 5 mg IV; may repeat 3x
- Vasopressors
  - Dopamine (Intropin)
    - Typical dose: 5 µg/kg/min; titrate up to max 50 µg/kg/min
  - Epinephrine
    - Typical dose: 0.05-2.00 µg/kg/min; titrate to blood pressure (BP) goal
  - Norepinephrine (Levophed)
    - Initial infusion: 8-12 µg/min; titrate to BP goal
    - Typical maintenance infusion: 2-4 µg/min
  - Phenylephrine
    - Initial infusion: 100-180 µg/min; titrate to BP goal
    - Typical maintenance infusion: 40-60 µg/min

Blood Products and Volume Resuscitation

- Albumin: Volume expander
  - Available as 5% or 25%
  - Commonly given after paracentesis > 5 L
    - Typical dose: 6-8 g/L of ascitic fluid removed
  - Can also be given for hypovolemia
    - Typical dose: 25 g IV
- Cryoprecipitate
  - Contains fibrinogen, factor VIII, von Willebrand factor, and factor XIII
  - Used for deficiency of any of above factors
    - Dose varies between factors
  - Most commonly used to replace fibrinogen
    - Typical dose: 10 units for fibrinogen replacement
    - 1 unit per 5-10 kg patient weight will increase fibrinogen by ~ 50-100 mg/dL
- Fresh frozen plasma (FFP)
  - Contains all coagulation factors
  - Used to correct INR for patients taking warfarin who need emergent or urgent procedure
    - Also used on patients with multiple factor deficiencies
  - Typical dose 12-15 mL/kg body weight
    - Will increase factor levels by 20-30%
    - 1 unit = 200 mL FFP
- Normal saline: Typical bolus 1 L, often reduced in CHF
- Platelets: Typical dose: 6 units
  - Raises platelet count by ~ 30,000-60,000/µL
- Red blood cells: 1 unit increases hemoglobin by ~1 g/dL

Contrast Reaction Management

- Albuterol inhaler: β agonist
  - Typical dose 2 puffs (180 µg)
    - Can repeat up to 3x
- Dextrose
  - Multiple dose options
    - PO: 2 sugar packets, 15-g tablets, or 4-oz juice
    - IV: 1 amp (25 g) D50W
- Diphenhydramine (Benadryl): Antihistamine
  - Typical dose: 50 mg PO or IV
- Epinephrine
  - Typical dose options
    - 0.1 mg (1 mL) of 1:10,000 IV
      - Can repeat up to 1 mg total
    - 0.3 mg (0.3 mL) of 1:1,000 IM
      - Can repeat up to 1 mg total
- Furosemide (Lasix): Typical dose: 20-40 mg IV
- Glucagon: Typical dose: 1 mg IM
- Labetalol: Typical dose: 20 mg IV
- Lorazepam (Ativan): Typical dose: 2-4 mg IV
- Nitroglycerin: Typical dose: 0.4 mg sublingual
  - Can repeat every 5-10 min

Contrast Reaction Pretreatment

- ACR Manual on Contrast Media, Version 10.2
- Elective premedication
  - Option 1
    - Prednisone 50 mg PO at 13, 7, & 1 hr before contrast
    - Diphenhydramine (Benadryl) 50 mg IV or PO 1 hr before contrast
  - Option 2
    - Methylprednisolone (Medrol) 32 mg PO at 12 and 2 hr before contrast
    - Optional: Diphenhydramine (Benadryl) 50 mg IV or PO 1 hr before contrast
- Emergency premedication
  - Preferred regimen
    - Methylprednisolone sodium succinate (Solu-Medrol) 40 mg **or** hydrocortisone sodium succinate (Solu-Cortef) 200 mg IV q 4 hr until contrast given
    - Diphenhydramine (Benadryl) 50 mg IV 1 hr before contrast
  - 2nd choice regimen

    - Dexamethasone sodium sulfate (Decadron) 7.5 mg IV **or** betamethasone 6 mg IV q 4 hr until contrast
    - Diphenhydramine (Benadryl) 50 mg IV 1 hr before contrast
  - Least preferable regimen
    - Diphenhydramine (Benadryl) 50 mg IV
  - Note: IV steroids have not been proven to be effective when given < 4-6 hours prior to contrast administration

Gastrointestinal

- Antinausea/antiemetics
  - Ondansetron (Zofran): Serotonin receptor blocker
    - Typical dose: 4 mg IV, 4-16 mg PO
  - Prochlorperazine (Compazine): Antipsychotic
    - Typical dose: 5-10 mg IV or PO
  - Promethazine (Phenergan): Antihistamine
    - Typical dose: 12.5-25 mg IV or PO
    - Has sedative effect
  - Metoclopramide (Reglan): Prokinetic
    - Typical dose: 10 mg IV, 10-15 mg PO
- To halt/decrease GI peristalsis
  - Improves DSA imaging (e.g., GI bleed study)
  - Glucagon: Typical doses
    - 0.2-0.5 mg IV to decrease stomach/small bowel
    - 0.50-0.75 mg IV to decrease colonic peristalsis
    - Increases blood glucose

Heart Rate Management

- Tachycardia due to atrial fibrillation
  - Diltiazem (Cardizem): Calcium channel blocker
    - Typical dose: 20 mg IV
      - Can repeat dose with 25 q 15 min
    - Typical infusion rate: 10-15 mg/hr
  - Propranolol (Inderal): β blocker
    - Typical dose 1 mg IV
    - May repeat dose after 2 min, max dose 2 mg q 4 hr
- Bradycardia management
  - Atropine: Anticholinergic agent
    - Typical dose: 0.5-1.0 mg IV

Hyperkalemia Management

- Calcium gluconate
  - Typical dose: 500 mg to 2 g IV
- Short-acting insulin (NovoLog, Humalog)
  - Typical dose: 5-10 units IV
  - Give with sugar to prevent hypoglycemia

Local Anesthesia

- Lidocaine: Amide
  - Usually 1-2%, ± epinephrine
  - Max subcutaneous dose: 4.5 mg/kg up to 300 mg without epinephrine, 7 mg/kg up to 500 mg with epinephrine
  - Up to 10 mg may also be given intraarterially prior to embolization (e.g., uterine artery embolization, chemoembolization)
- Chloroprocaine: Ester
  - May be used for patients with lidocaine allergies
  - Max subcutaneous dose: 11 mg/kg up to 800 mg without epinephrine, 14 mg/kg up to 1,000 mg with epinephrine
- Diphenhydramine (Benadryl): Antihistamine
  - 1% solution may be used in patients allergic to amide and ester local anesthetics
  - Monitor for sedative effects

Miscellaneous

- Octreotide: Somatostatin analog
  - Prior to adrenal biopsy, chemoembolization of hormonally active neuroendocrine tumors
    - 200 µg subcutaneous

Reversal Agents

- Benzodiazepine reversal
  - Flumazenil (Romazicon): Benzodiazepine antagonist
    - Typical dose: 0.2 mg IV every min
      - Repeat dose every 1 min for max dose of 1 mg
    - **May be shorter acting than benzodiazepines**
      - Monitor patient closely
- Heparin reversal
  - Protamine sulfate
    - Typical dose: 10 mg/1,000 units heparin given
      - Dose may be decreased based on time since last heparin administration
- Opioid reversal
  - Naloxone (Narcan): Opioid antagonist
    - Typical dose: 0.1-0.2 mg IV every 2-3 min
    - **Often shorter acting than opioids**
      - **Patient must be closely monitored and may need multiple doses**
    - May cause nausea, withdrawal
- Warfarin reversal
  - Vitamin K (phytonadione)
    - Typical dose: 1.0-2.5 mg PO
  - FFP for emergent reversal

Sclerosants

- Some can be mixed with air to create foam
  - Improves surface contact and reduces sclerosant dose
- Sodium tetradecyl sulfate (STS) (Sotradecol)
  - Typically use 3% concentration
  - Foam mixture: 3 (air): 2 (STS): 1 (lipiodol)
  - Typical dose: ≤ 2 mL
- Bleomycin
  - Typical dose: 1 unit/cc foam (e.g., 6 units bleomycin in 1 mL saline + 1 mL albumin + 4 mL air)
- Ethanol: Strong sclerosant, use caution
  - Typical dose: 25-50% of estimated volume to sclerose
  - Nerve damage and necrosis of skin/mucosa possible
- Additional sclerosants available

Vasospasm Management

- Nitroglycerin: Vasodilator
  - Typical dose 100-200 µg IV or IA
- Verapamil: Calcium channel blocker
  - Typical dose: 2.5 mg IV

SELECTED REFERENCES

1. American College of Radiology Manual on Contrast Media. V10.2 https://www.acr.org/quality-safety/resources/contrast-manual. Reviewed March 28, 2017. Accessed March 28, 2017.

Recommendations for Administration of Prophylactic Antibiotics

Procedure	Routine Prophylaxis Recommended?	Antibiotic Options
Angiography, angioplasty, stenting	No	1 g cefazolin (Ancef)
Inferior vena cava filter placement	No	
Embolization, hepatic (bland or chemoembolization)	Yes	1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; 1 g cefazolin (Ancef) IV and 500 mg metronidazole (Flagyl) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV; 1 g ceftriaxone (Rocephin) IV
Embolization, renal or splenic	Yes	1 g ceftriaxone (Rocephin) IV
Uterine artery embolization	Yes	1 g cefazolin (Ancef) IV; 900 mg clindamycin (Cleocin) IV and 1.5 mg/kg gentamicin (Garamycin) IV; 2 g ampicillin (Principen) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV
Transjugular intrahepatic portosystemic shunt	Yes	1 g ceftriaxone (Rocephin) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV
Gastrostomy/gastrojejunostomy placement	Yes if pull technique, no consensus if push technique	1 g cefazolin (Ancef) IV
Hepatobiliary interventions	Yes	1 g ceftriaxone (Rocephin) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV
Genitourinary interventions	Yes	1 g cefazolin (Ancef) IV; 1 g ceftriaxone (Rocephin) IV; 1.5-3 g ampicillin/sulbactam (Unasyn) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV
Tumor ablation	No consensus	Liver: 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; renal or bone: 1 g ceftriaxone (Rocephin) IV
Abscess drainage	Yes	1-2 g cefoxitin (Mefoxin) IV q 6 hr; 1-2 g cefotetan (Cefotan) IV q 12 hr; 3 g ampicillin/sulbactam (Unasyn) IV q 6 hr; 3.375 g piperacillin/tazobactam (Zosyn) IV
Percutaneous biopsy	Not unless biopsy transrectal	80 mg gentamicin (Garamycin) IV/IM plus 250 mg ciprofloxacin (Cipro) PO 2x daily x 5 days
Vertebral body augmentation	Yes	1 g cefazolin (Ancef) IV
Patients with penicillin allergies may be given vancomycin or clindamycin as well as an aminoglycoside antibiotic, such as gentamicin.		

Adapted from: Venkatesan AM et al: Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Interv Radiol. 21(11):1611-30; 2010.

Antibiotic Classes and Coverage

Antibiotic Class	Example Medication	Coverage
Aminoglycosides	Gentamicin	gram-negative aerobes, *Pseudomonas*
Cephalosporins: 1st generation	Cefazolin	Skin flora, including *Staphylococcus aureus*, basic gram negative
Cephalosporins: 2nd generation	Cefoxitin	Decreased *S. aureus* coverage compared to 1st generation but better gram-negative coverage and some anaerobic coverage
Cephalosporins: 3rd generation	Ceftriaxone	Decreased coverage of gram positives, including *S. aureus* compared to 1st and 2nd generations but with improved gram-negative coverage and some coverage of *Pseudomonas*
Cephalosporins: 4th generation	Cefepime	Similar to 3rd generation but with improved *Pseudomonas* coverage
Glycopeptide	Vancomycin	gram positive, *Streptococcus*, *Staphylococcus*, MRSA
Lincosamide	Clindamycin	MRSA, anaerobes

Antibiotic Classes and Coverage (Continued)

Antibiotic Class	Example Medication	Coverage
Penicillins: 3rd generation	Ampicillin	*Streptococcus*, basic gram negative
Penicillins: 4th generation	Piperacillin	*Pseudomonas*
Quinolones: 2nd generation	Ciprofloxacin	gram negative, *Pseudomonas*, *S. aureus* (not MRSA)
Quinolones: 3rd generation	Levofloxacin	gram negative, *Pseudomonas*, gram positive, *S. aureus* (not MRSA)
Nitroimidazole	Metronidazole	Anaerobes

Treatment of Contrast Reactions

Symptoms	Treatment
All reactions	Maintain IV access Monitor vitals Provide supplemental O_2 as needed Call rapid response, code, or 911 as needed
Anxiety (diagnosis of exclusion)	Reassure patient
Bronchospasm	Mild: 2 puffs (180 µg) albuterol inhaler Moderate: Albuterol plus consider 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Severe: Albuterol **and** 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
DIffuse erythema	6-10 L/min O_2
Hives	25-50 mg diphenhydramine (Benadryl) PO or IV
Hypoglycemia	6-10 L/min O_2 If patient can safely swallow: Oral glucose (2 sugar packets or 15 g of tablets or 4 oz fruit juice) If patient unable to safely swallow: 1 amp (25 g) D50W IV Unable to swallow and no IV access: 1 mg glucagon IM
Hypotension	1 L bolus of normal saline Elevate legs If unresponsive to fluids: 0.1 mg (1 mL) epinephrine 1:10,000 IV (preferred) **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Hypotension with bradycardia (vasovagal)	If unresponsive to fluids and supplemental oxygen: 0.6-1.0 mg atropine IV
Hypotension with tachycardia (anaphylaxis)	0.1 mg (1 mL) epinephrine 1:10,000 IV (preferred) **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Hypertensive crisis	6-10 L/min O_2 20 mg labetalol IV **or** 0.4 mg nitroglycerin sublingual **and** 20-40 mg furosemide (Lasix) IV Call rapid response, code, or 911 as needed
Laryngeal edema	6-10 L/min O_2 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Pulmonary edema	6-10 L/min O_2 Elevate head of bed 20-40 mg furosemide (Lasix) IV Call rapid response, code, or 911 as needed
Seizures	Protect patient and turn on side Suction airway as needed 6-10 L/min O_2 If not resolving spontaneously: 2-4 mg lorazepam (Ativan) IV Call rapid response, code, or 911 as needed

Adapted from American College of Radiology Manual on Contrast Media. V10.2 https://www.acr.org/quality-safety/resources/contrast-manual. Reviewed March 28, 2017. Accessed March 28, 2017.

Angioplasty

KEY FACTS

TERMINOLOGY

- **Angioplasty**: Inflation of catheter-mounted balloon within narrowed vessel; controlled fracture of obstructing plaque enlarges lumen, improves flow

PROCEDURE

- Selectively catheterize target artery/vein
  - Administer heparin bolus prior to crossing lesion
- Gently advance guidewire across stenosis
  - Imperative to avoid dissection
  - If resistance to guidewire passage, do not continue to advance wire; stop, reorient wire/catheter
  - Keep catheter parallel to vessel centerline
- Advance diagnostic catheter over wire, across lesion
  - Exchange crossing wire for stiff guidewire
- Replace diagnostic catheter with PTA catheter
  - Perform angioplasty; use insufflator
- Remove PTA catheter, leave guidewire across lesion
  - Document results with DSA imaging

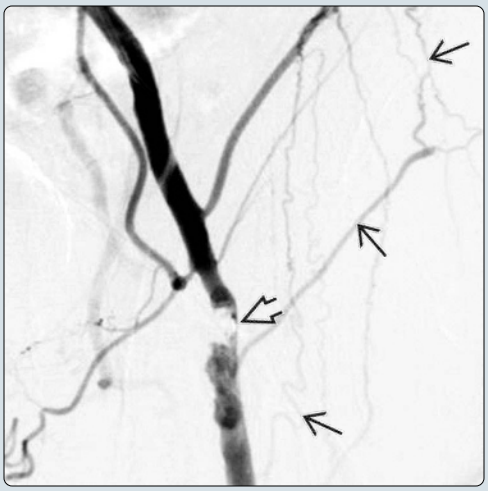
POST PROCEDURE

- Consider antiplatelet regimen after arterial procedure
- Consider anticoagulant regimen after venous procedure
- Arrange patient follow-up
  - Order imaging/noninvasive studies as needed
  - Schedule clinical appointment

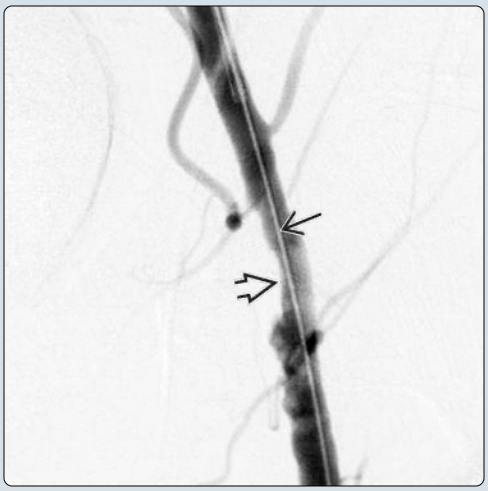
OUTCOMES

- Technical and clinical success rates depend on
  - Lesion length, location, morphology; runoff status
  - Restenosis (rate may be up to 40%)
  - Drug-eluting balloon restenosis rates may be favorable to conventional angioplasty
- Most significant potential complications
  - Vessel rupture (reinflate balloon to stabilize)
  - Distal embolization, thrombosis

Common Femoral Artery Eccentric Stenosis (Pre-Angioplasty)

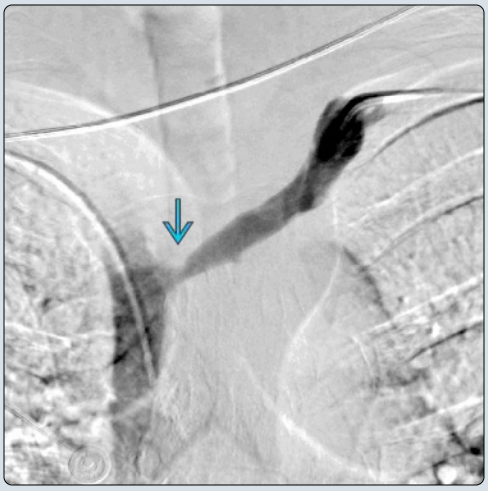


Common Femoral Artery Eccentric Stenosis (Post Angioplasty)

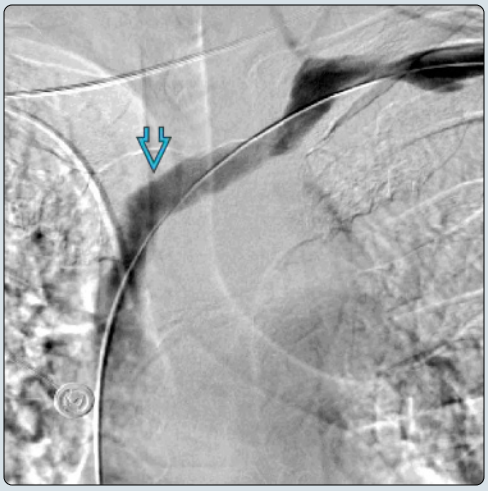


(Left) *Anteroposterior DSA of the left common femoral artery shows a focal, eccentric, high-grade stenosis. Note the numerous collaterals that are present, further confirming the significance of the stenosis.* **(Right)** *Postangioplasty DSA shows a normal luminal caliber at the site of prior stenosis. A guidewire was left in place across the stenosis until angiographic confirmation of a satisfactory result. The collaterals no longer fill.*

Symptomatic Central Venous Stenosis of Hemodialysis (Pre-Angioplasty)



Symptomatic Central Venous Stenosis of Hemodialysis (Post Angioplasty)



(Left) *Angioplasty, with or without stent placement, is the recommended treatment for symptomatic central venous stenosis (CVS) by the Kidney Disease Outcomes Quality Initiative (K/DOQI).* **(Right)** *PTA has high initial angiographic success (70-90%). However, PTA disrupts the vessel intima and triggers accelerated neointimal hyperplasia (i.e., recurrent stenosis). Also, CVS primary stenting does not improve primary patency vs. PTA. Thus, avoid any intervention in asymptomatic patients.*