Non-Invasive Vascular Imaging: A Comprehensive Review

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BACKGROUND

- Vascular imaging intersects with all aspects of the body, crosses all sub-specialties within radiology, and involves multiple imaging modalities.
- Given the various imaging options, it is important for radiologists and trainees to have a strong foundational understanding of the appropriateness of each modality whether in the setting of surveillance, an acute presentation, or a chronic presentation.

PURPOSE

- This educational exhibit will:
  1. Provide the viewer a better understanding of imaging appropriateness criteria in the setting of vascular imaging
  2. Examine key vascular imaging protocols that are used while on call
  3. Use a case-based review to discuss vascular disease processes that can be identified throughout the body using non-invasive imaging.

METHODS

- We performed a literature search to evaluate the appropriateness criteria for various vascular imaging modalities.
- Cases were acquired from our institution's Electronic Medical Record Search Engine (EMERSE) and our institution's imaging protocols were reviewed.

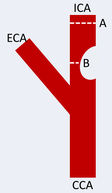
ADVANTAGES AND DISADVANTAGES PER IMAGING MODALITY

Ultrasound	CT Angiography	MR Angiography
ADVANTAGES		
• No radiation	• Quick	• No radiation
• Real time	• Vascular anatomic detail	• Thrombus evaluation
• Document velocity	• Visualize deep vessels	• Vessel wall evaluation
• Physiologic changes	• Evaluate larger calcified vessels	• Vascular anatomic detail
• Relatively Inexpensive	• Widely available	• Visualization of deep vessels
DISADVANTAGES		
• Time consuming	• Radiation exposure	• Expensive
• Requires skilled sonographer	• IV Contrast administration	• IV contrast administration
• Operator dependent	• Calcifications obscure small vessels	• Requires cooperative patient
• Artifacts from stents & calcs	• Limited evaluation of stent patency in small vessels	• Artifacts from stents & calcs
• Decreased quality for deep vessels		• Limited evaluation of stent patency in small vessels

CAROTID ARTERY IMAGING

Screening/ surveillance	Acute symptoms, Recurrent Stroke, Surgery/Intervention
Doppler US *only if patient has risk factors	CTA or MRA (+/- Doppler US)

North American Symptomatic Carotid Endarterectomy Trial (NASCET) Measurem
MRA and CTA – 3D stenosis evaluation



Diameter stenosis $\frac{(A-B)}{A} \times 100\%$

Digital subtraction angiography is still considered the gold standard for carotid artery imaging.

Asymptomatic 70-99% stenoses or symptomatic 50-99% are appropriate to treat

Doppler Ultrasound Velocity Criteria

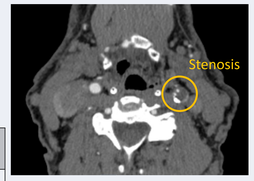
Degree of stenosis (%)	ICA PSV (cm/sec)	ICA EDV (cm/sec)	ICA/CCA PSV ratio
>/= 70% but less than near occlusion	>230	>100	>4.0

CTA Carotid Protocol
- *Used for carotid stenosis, carotid dissection, AV malformation, aneurysm, pseudoaneurysm*
- 60 cc Isovue 370
- Rate: 5 cc/s
- FOV: Below arch to superior ridge of orbit

MRA Carotid Protocol
Used for dissection, stroke, atherosclerotic disease evaluation
- Time of flight – no contrast, susceptible to artifact
- 20 mL Multihance
- Rate: 2 cc/s
- Sequences: Axial T1, Axial T2, Coronal T1 SPACE, Dynamic 3D

Carotid Artery Stenosis Case

65-year-old male with history of multiple transient ischemic attacks with right sided weakness.



THORACIC VASCULAR IMAGING

Acute Aortic Syndrome	Aortitis	Aneurysm
CTA (quick)	MRA (and PET) *for wall inflammation	Acute complication →CTA Surveillance→ US, CTA, or MRA

Pulmonary Embolism Protocol
- CT PE: >90% sensitivity, >90% specificity
- FOV: lowest hemidiaphragm to above apices
- Rate: 70 mL @ 5 mL/s, 7 second pause, 50 mL at 3 mL/s
- Bolus Tracking ROI: Main PA

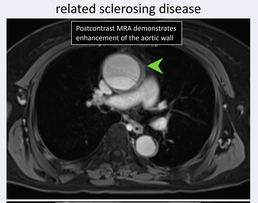
Acute Aortic Syndrome (Dissection, intramural hematoma, penetrating atherosclerotic ulcer, thoracic aortic aneurysm)
- CTA: 100% sensitivity*, 98% specificity (Thoracic Aortic Dissection)
- May be non-gated, prospective (stable HR, within 5 bpm variation) or retrospective gated
- Noncontrast and contrast enhanced
- FOV: 2 cm above arch to celiac artery
- Rate: 100 mL at 4 mL/s
- Bolus Tracking: ROI: Ascending or Descending aorta

Double and Triple Rule out (CT PE/Aorta & Cardiac)
Triple Rule Out studies were shown to not reduce need for additional imaging, cost, or length of stay.[1]

[1]Rogers I.S., Banerji D., Siegel E.L., et al. (2011) Usefulness of comprehensive cardiothoracic computed tomography in the evaluation of acute undifferentiated chest discomfort in the emergency department (CAPTURE). Am J Cardiol 107:643-650

Aortitis Case

68-year-old female with history of IgG4-related sclerosing disease

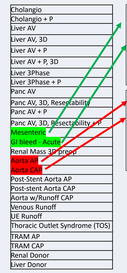


ABDOMINAL VASCULAR IMAGING

Contrast Phases		
Phase	Time after injection (sec)	Most common Uses
Non-contrast	-	Renal stones Fatty lesions
Early arterial	15-20	Artery pathology
Late arterial	35-40	Hypervascular lesions Mesenteric ischemia
Hepatic phase	70-80	Hypovascular liver lesions
Nephrogenic	100	RCC
Delayed	6 min	Urothelial cancer Fibrotic lesions

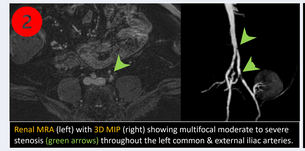
Degree of stenosis (%)	Celiac axis	Superior Mesenteric Artery	Inferior Mesenteric Artery
>/= 70%	PSV >320 cm/s EDV >100 cm/s	PSV >395 cm/s EDV >74 cm/s	PSV >270 cm/s EDV >100 cm/s

CT Protocols with Arterial Phase Imaging

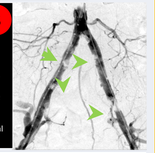


- **Mesenteric**: volume negative contrast, delayed phase at 65 s.
- **GI Bleed**: Isovue positive contrast, includes noncontrast, delayed phase at 80 s.
- **Aorta**: arterial phase only; ***unless acute aortic syndrome suspected or postoperative history, then include non-contrast phase

*ALL **pseudoaneurysms** should be treated as impending rupture, with IR evaluation prior to leaving hospital.*



Renal MRA (left) with 3D MIP (right) showing multifocal moderate to severe stenosis (green arrows) throughout the left common & external iliac arteries.



Contrast enhanced angiogram showing multifocal moderate to severe stenosis (green arrows) throughout the left common, right common, and left external iliac arteries.

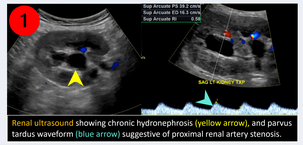
Aneurysms: Use the Society of Vascular Surgery guidelines for screening, surveillance, treatment, and follow-up of visceral artery aneurysms

Contrast enhanced angiogram (left) showing improved vascular flow post stenting & renal ultrasound (right) showing resolution of parvus tardus waveform (blue arrow). Patient had improved renal function.

Acute mesenteric ischemia	Chronic mesenteric ischemia
CT Mesentery: to exclude proximal acute arterial thrombosis, distal embolic arterial thrombosis, portal venous thrombosis.	*CT Mesentery and/or DVU Mesentery:* typically, patients become symptomatic when 2/3 vessels develop flow-limiting stenoses.

Iliac Artery Stenosis Case

64-year-old male with a history of 8-year-old renal transplant with worsening renal function.



Renal ultrasound showing chronic hydronephrosis (yellow arrow), and parvus tardus waveform (blue arrow) suggestive of proximal renal artery stenosis.

PERIPHERAL VASCULAR IMAGING

Acute Limb Ischemia	Claudication
• Angiography • CTA with runoff (planning)	• CTA with runoff • MRA with runoff • Doppler, ABI/TBI, PVR • Angiogram (intervention)

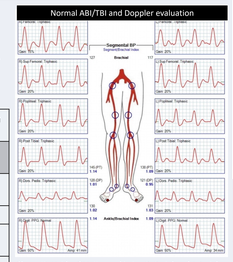
Inflow: aortoiliac & femoropopliteal

Outflow: crural/ tibiopedal

ABI/TBI: BP at ankle/toe divided by BP in arm

Vessel Disease	ABI	TBI
Calcified Vessel	>1.4	Unaffected
Normal	0.9-1.4	>0.6
Mild PAD	0.7-0.89	0.34-0.59
Moderate PAD	0.51-0.69	0.12-0.34
Severe PAD	<0.5	<0.11

Normal ABI/TBI and Doppler evaluation



Cheun TJ, Haidar GM, Toursarkissian B. Peripheral Arterial Disease and Diabetes Mellitus. *The Diabetes Textbook*. 2019:747-763. doi:10.1007/978-3-030-11815-0_48.

Case of Leriche Syndrome

93-year-old female with thigh claudication & foot pain at rest.

Curved planar reformatted CT angiography demonstrating an occluded infrarenal abdominal aorta (inflow disease).

ABI/TBI evaluation with biphasic and monophasic doppler waveforms throughout and bilateral decreased ABI/TBIs

Lower Extremity Doppler Waveform	Significance
Triphasic	Normal
Biphasic	Abnormal if transitions from triphasic
Monophasic	Always abnormal

Pulse Volume Record (PVR) measures volume of blood traveling through segment during systole.

Normal | Abnormal

1. Decreased amplitude
2. Flattened peak
3. Absent dicrotic notch