Arteriovenous Fistulas: Complications of a Gunshot Wound
Goals of the Presentation

With the help of our **index patient**, we will:

1) Review the **vascular anatomy** of the lower extremity
2) Learn the **diagnostic tests** available to evaluate for extremity vascular trauma
3) Generate a **differential diagnosis** of lower extremity vascular pathology in the setting of trauma
4) Learn the **radiologic findings** of extremity vascular trauma on CT angiogram.
5) Learn the **limitations** of CT angiogram in assessing vascular trauma
Index Patient Presentation

• **HPI:** 21 yo M s/p *gun shot wound to the left upper medial thigh* with no exit wound. Absent PT/DP pulses at the scene.

• **ROS:** Pain at entry site. Denies pain and numbness in left calf and foot. All other systems are normal.

• **PMH:** Bipolar Disorder, Attention Deficit Disorder

• **Medications:** None

• **Allergies:** Morphine
Index Patient: Physical Exam

T: 98.8   HR: 83   BP: 145/72   RR: 22   O2 sat: 100%

- **Neuro/Psych**: A&O x3, NAD
- **Cardiac**: Regular rate & rhythm, no m/r/g
- **Pulmonary**: Clear to auscultation, normal effort
- **Extremities**:
  - Entry wound in left medial thigh, no exit wound
  - Pulses: RLE femoral, popliteal, PT and DP – Palpable
  - LLE femoral popliteal, PT and DP – Palpable
  - No femoral bruit/thrills
  - No lower extremity edema, compartments soft
  - Strength and sensation intact bilaterally
Clinical Questions

With an overall benign exam, does our patient need further evaluation for vascular trauma?

What are the clinical signs of arterial injury in extremities?
Clinical Signs of Arterial Injuries in the Extremities

- Clinical signs of arterial injuries are divided into **Hard Signs** and **Soft Signs**
- Our patient merits further workup since his injury is near major vessels – the femoral artery and vein

<table>
<thead>
<tr>
<th>Clinical Signs of Arterial Injuries in Extremities</th>
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<tr>
<td><strong>Hard Signs</strong></td>
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<tr>
<td>* Absent or diminished pulses</td>
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<tr>
<td>* Active hemorrhage</td>
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<tr>
<td>* Large expanding or pulsatile hematoma</td>
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<tr>
<td>* Bruit/thrill</td>
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<td>* Distal ischemia</td>
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Clinical Signs of Arterial Injuries in the Extremities: Pulse or No Pulse

While it is important to remember the hard and soft clinical signs of arterial injuries, a major take away point from our patient is:

**Palpable pulses does NOT exclude vascular injury**
Objectives of Imaging Our Patient

The objectives of imaging our patient is to assess the following:

- What is the path of the projectile?
- Is there osseous and/or soft tissue injury?
- Is there vascular trauma?

Continue to the next slide for a discussion of possible imaging modalities.

Menu of Imaging Tests

- **Plain film**
  - Reveals osseous fractures that could jeopardize adjacent vessels, but not vasculature itself

- **Ultrasound (US)**
  - Color-flow duplex scanning demonstrates the integrity of vessels and flow velocity/directionality; however, US is extremely operator dependent

- **Conventional angiography**
  - Identifies vascular injury and has interventional capacity; however, this is an invasive procedure and does not provide information regarding the foreign body pathway or osseous/soft tissue structures

- **X-ray Computed Tomography (CT) Angiogram**
  - Identification of vascular injury, osseous damage, and foreign body location

- **MRI**
  - Identification of vascular injury and soft tissue damage; however, this is an expensive, more time-consuming imaging modality

Despite the broad menu, CTA is the test of choice for our patient.

Continue onto the next slide to learn more about CTA versus conventional arteriography.
Conventional Angiography vs CTA

- Studies comparing CTA of the extremities with conventional angiography have found CTA to be:
  - Comparable in accuracy
  - More time-efficient
  - Less invasive
  - Less expensive

- Literature Highlight: In a prospective study of 139 patients, CT angiography was used as the initial imaging modality in the setting of trauma to the extremities
  - Sensitivity 95.1% for proximal arterial injuries in the upper and lower extremities
  - Specificity 98.7% for proximal arterial injuries in the upper and lower extremities

Before reviewing our patient’s CTA images, it is imperative we review lower extremity vascular ANATOMY.

The “Must Know” Arteries

Femoral Artery
- Superficial femoral artery
- Deep artery of thigh

Popliteal Artery

Anterior tibial artery

Posterior tibial artery

Fibular artery
Posterior Crural Compartment: Artery Names and Locations

- The popliteal artery divides into the anterior tibial and the posterior tibial artery.

- The posterior tibial artery gives rise to the fibular artery.

- The posterior tibial artery courses medially while the fibular artery courses laterally.

The anterior tibial descends and gives rise to the dorsalis pedis artery.

The perforating branch of fibular artery supplies the lateral malleolus.
Superficial and deep femoral arteries and veins travel through the anterior compartment of the thigh (outlined in purple).

*Remember: Keep this image in mind when reviewing our patient’s axial CTA images!
Vascular Anatomy of Crural Compartments

**Anterior Compartment (Purple)**
- Anterior tibial artery and vein

**Posterior Compartment (Teal)**
- Posterior tibial artery and vein
- Fibular artery and vein

**Lateral Compartment (Yellow)**
- None

*Remember: Keep this image in mind when reviewing our patient’s axial CTA images!*

Axial CTA of the pelvis shows **TWO** contrast enhanced vessels (femoral artery and femoral vein) on the patient’s left side. The patient’s right side shows only **ONE** contrast enhanced vessel (femoral artery).

**Blue Arrow:** Femoral Artery

**Yellow Arrow:** Femoral Vein
If the CTA was timed properly, only the arteries should be filled with contrast. Thus, either our test is faulty OR our patient has a connection between an artery and vein in his left lower extremity, causing contrast to enter the venous system.

Blue Arrow: Femoral Artery
Yellow Arrow: Femoral Vein
As we continue down our patient’s leg, we note the bifurcation of the femoral artery into the **superficial femoral artery** and **deep femoral artery**. We also note contrast in the **superficial femoral vein**.
Index Patient CTA: Arteriovenous Fistula

As we continue down the axial CTA, we notice a stream of contrast between the superficial femoral artery and vein. This is suggestive of an arteriovenous (AV) fistula between the artery and vein, which would explain why veins contain contrast.
This axial CTA of the lower extremity distal to the AV fistula shows an opacity in the superficial femoral vein, suggestive of either a clot or intimal flap.

In addition, please note the increased diameter of the left thigh, suggestive of internal hemorrhage and soft tissue swelling.

Yellow Arrow = Clot or Intimal Flap
Distal to the AV fistula, we find a foreign body – the bullet. Please note the streak artifact created by the foreign body; this will be important when discussing the limitations of CTA studies.
As we continue down the lower extremity CTA, we note both popliteal arteries contain contrast, suggesting adequate perfusion distal to the AV fistula.

No veins contain contrast on this image.
Index Patient CTA: Crural Perfusion

This lower extremity axial CTA shows all three vessels of the calf (posterior tibial, anterior tibial, and fibular artery) contain contrast, suggesting adequate perfusion and thus decreased risk of ischemic limb. Remembering the crural compartments make it easier to determine the location of the three arteries.

Pink Arrow = Posterior Tibial Artery
Blue Arrow = Fibular Artery
Yellow Arrow = Anterior Tibial Artery
Causes and Complications of Arteriovenous Fistulas

- **Cause**
  - Simultaneous injury of an adjacent artery and vein

- **Mechanism**
  - Venous pressure is lower than arterial pressure; thus, arterial contents will flow into the venous system
  - Flow through an arteriovenous fistula is continuous

- **Physical exam**
  - Accentuation of the bruit and thrill detected over fistula during systole

- **Long-standing complications**
  - Venous congestion
  - High-out cardiac failure

Comparison Patient 1: Subacute Arteriovenous Fistula

- This volume-rendered CT angiogram shows an AV fistula between anterior tibial artery and vein (long arrow)
- The anterior tibial artery is enlarged above the level of arteriovenous fistula and smaller distally (short arrows)
- Dilated veins are shown throughout image, suggesting a subacute or chronic process
- Retained BB pellet indicated by short arrow

CTA Signs of Arterial Injury

In addition to AV fistulas, CTA can show other signs indicative of arterial injury:

- **Extravasation** of contrast material
- **Pseudoaneurysm**
- **Vessel caliber reduction**
  - Spasm
  - Dissection or partial-thickness wall injury
  - External compression
  - Thrombus/Intimal Flap

On the following slides, we will show examples of each
Comparison Patient 2
Extravasation on CTA

• On this coronal CTA of the right lower extremity, note the active contrast extravasation (large arrow) from the superficial femoral artery
  • This sometimes described as a ‘contrast blush’

• A small hole measuring approximately 1mm was discovered during surgery and repaired with primary sutures

Comparison Patient 3:
Pseudoaneurysm on Angiogram

- **Pseudoaneurysms** are leaks contained by surrounding tissues and local fibrosis
  - Simply said: A contained rupture

- Pseudoaneurysm wall is NOT formed by vascular tissue, but develops from organized thrombus, associated fibrosis, and surrounding tissues

Selective mesentric angiogram showing a pseudoanuerysm related to the left gastric artery

Comparison Patient 4: Pseudoaneurysm on CTA

This volume-rendered CTA and reformatted coronal CTA of the right lower extremity show a small pseudoaneurysm arising from the proximal anterior tibial artery (arrows).

Comparison Patient 5: Vessel Caliber Reduction

**Image A:** Sagittal reformatted CT angiographic image of lower extremity shows loss of opacification of popliteal artery (white arrow).

**Image B:** Conventional arteriogram confirms loss of opacification of popliteal artery suggestive of transection (black arrow).

Comparison Patient 6: Vessel Caliber Reduction

Coronal and sagittal CTA of lower extremity showing focal lumen narrowing of left popliteal artery. During surgical exploration, an intimal flap was found at this site and repaired.

CTA Imaging Shortcomings

- **Poor arterial opacification**
  - Transit of contrast bolus and timing of image
  - Vessel underfilling from injury or poor cardiovascular health

- **Atherosclerosis**

- **Displaced fracture fragments**

- **Artifacts from metal/foreign body**

  ★ **Streak artifacts are the major limiting factor**

  Please proceed to next slide for example

Example of Streak Artifacts

Non-diagnostic CTA with metallic streak artifact after shotgun injury to the lower extremity

Index Patient: Surgical Intervention

- Patient underwent repair of arteriovenous fistula:
  - Evidence of through-and-through injury to both the artery and vein with subsequent fistula formation
  - **Vein**: Following debridement, 2-inch segment of left greater saphenous vein used to patch femoral vein
  - **Artery**: More than 70% had been transected; surgeons divided artery in half and mobilized it to allow for primary reanastomosis
  - Small strip of vastus medialis muscle (1.5cm x 6cm) was interposed between two repair vessels to prevent re-fistulization
US color doppler images show no evidence of left superficial femoral arteriovenous fistula; red and blue colors indicate flow in opposite direction and do NOT mix. There is no other evidence of other abnormalities in the vessels.
Conclusions

With the help of our index patient, we have:

1) Reviewed the **vascular anatomy** of the lower extremity

2) Learned the clinical indications for vascular imaging in the setting of a trauma
   - **Palpable distal pulses is NOT enough to exclude vascular injury**

3) Learned that **CT angiogram** is a sensitive and specific test to evaluate for extremity vascular trauma
   - Limitations include **poor arterial opacification** and **streak artifacts**

4) Learned the **radiologic findings** of extremity vascular trauma on CT angiogram
   - Contrast extravasation
   - Vessel caliber reduction
   - Pseudoaneurysm
   - Arteriovenous fistula formation
Bibliography

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