Diagnosis and management of peripheral vascular injuries

Introduction

- Patients of all ages and sexes are at risk for VT
- less common among the elderly, children, and women
- Blunt trauma is the most common cause of VT among children and in most civilian trauma series
- Arterial injuries (AIs) are diagnosed more often than venous injuries
- lower extremities are injured more often than upper extremities in adults

obayashi L, Coimbra R, Goes AMO Jr, Reva V, Santorelli J, Moore EE, Galante J, Abu-Zidan F, Peitzman AB, Ordonez C, Maier RV, Di Saverio S, Ivatury R, De Angelis N, Scalea T, Catena F, Kirkpatrick A, Khokha V, Parry N, Civil I, Leppaniem Chirica M, Pikoulis E, Fraga GP, Chiarugi M, Damaskos D, Cicuttin E, Ceresoli M, De Simone B, Vega-Rivera F, Sartelli M, Biffl W, Ansaloni L, Weber DG, Coccolini F. American Association for the Surgery of Trauma-World Society of mergency Surgery guidelines on diagnosis and management of peripheral vascular injuries. J Trauma Acute Care Surg. 2020 Dec;89(6):1183-1196. doi: 10.1097/TA.0000000000002967. PMID: 33230048.

- Two thirds of upper extremity arterial injuries (UEAIs) are distal (radial and ulnar arteries), and one third are proximal (primarily brachial artery)
- the most common lower extremity arterial injury (LEAI) to be the popliteal and superficial femoral arteries (SFAs)
- The femoral artery is also the most frequently injured vessel in combat
- The extent of blood loss and rates of hemodynamic instability upon admission are higher in more proximal Ais, which also have a larger proportion of severe associated injuries

Incidence

- Vascular injuries are unevenly distributed between body regions
- many patients have injured more than one vessel.
- in the thorax (25%)
- abdomen/pelvis (25%),
- upper (25%) and lower extremities (20%)
- in the neck (10%)
- Among military casualties, extremity injuries account for 70% or more of VTs with the lower extremity

Mechanism of injury

- Among adult penetrating injuries, gunshot wound (GSW) and stab wound account for the majority of VT cases in civilian practice
- In children younger than 6 years, falls and road traffic accidents are the most common causes of blunt trauma, while glass cuts are the most common cause of penetrating injuries

TABLE 2. AAST Organ Injury Scale Grading PVI[51]

Grade	Injury
I	Digital artery/vein, palmar artery/vein, deep palmar artery/vein, dorsalis pedis artery, plantar artery/vein, nonnamed arterial/venous branches
II	Basilic/cephalic vein, saphenous vein, radial artery, ulnar artery
III	Axillary vein, superficial/deep femoral vein, popliteal vein, brachial artery, anterior tibial artery, posterior tibial artery, peroneal artery, tibioperoneal trunk
IV	Superficial/deep femoral artery, popliteal artery
V	Axillary artery, common femoral artery

PVI

- can be occlusive or nonocclusive depending on vascular patency.
- Nonocclusive injuries are presented as :
- intimal irregularity/tear (Grade I, <25% narrowing), dissection/intramural
- hematoma (Grade II, ≥25% narrowing)
- partial transection with PSA formation (Grade III).
- Occlusive injuries include:
- thrombotic occlusion (Grade IV, vessel wall is preserved)
- complete transection (Grade V).

Clinical Presentation and Diagnosis of PVI

TABLE 3. Clinical Signs of PVI

Hard Signs	Soft Signs
Pulsatile bleeding	Nonpulsatile bleeding
Expanding/pulsating hematoma	Nonexpanding/nonpulsatile hematoma
Loss of distal pulses	Diminished pulse
Bruit/thrill	History of arterial (massive) bleeding/hypotension
	Previously applied tourniquet
	Neurologic deficit
	Wound in proximity to named vessel

Clinical Presentation and Diagnosis of PVI

- A structured physical examination is mandatory in the diagnostic work-up of an injured extremity. Patients with “hard” and “soft” signs of PVI should be evaluated without delay. (GoR 1B)
- Patients with hard signs of PVI should be transported directly to the operating room for surgical exploration. Where available, patients with multilevel penetrating injuries and those with blunt PVI may benefit from use of a hybrid operating room with the ability to perform on table angiography for both diagnostic and therapeutic purposes. When not available, C-arm can be used for on-table angiography to augment surgical exploration and repair. (GoR 1B)

- Hemodynamically unstable patients with soft signs of PVI should be transported to the operating room, with or without endovascular capability, for resuscitation and appropriate evaluation/intervention. (GoR 2B)
- Presence of peripheral pulses alone cannot reliably exclude AI. For hemodynamically stable patients with concerning mechanism, proximity injury, or soft signs of PVI, additional evaluation with ankle brachial index (ABI) or arterial pressure index (API) measurements is required. (GoR 1B)

- Ankle brachial index and API are effective screening methods for detecting major AI; an ABI/API of >0.9 generally excludes the need for additional imaging. (GoR 1B)
- Patients with knee dislocations are at higher risk of occult popliteal artery injury. Normal distal pulse upon PEX does not exclude popliteal artery injury. Additional imaging including formal or computed tomography angiography (CTA) may be beneficial. (GoR 2B)

- Computed tomography angiography is recommended as the first-line modality for investigating blunt and penetrating PVIs in adults and children who are hemodynamically stable without active bleeding. (GoR 1B)
- Invasive catheter angiography should be reserved for patients in need of interventional procedures, if vasospasm is clinically suspected or when CTA is unavailable, equivocal, or nondiagnostic due to artifact from retained metallic objects.(GoR 1B)

- Patients with penetrating extremity trauma (having no other injuries) who present with normal PEX and normal ABI/API may be safely discharged (GoR 1B). These patients, however, should be followed up in an outpatient setting because of the risk of delayed PSA

- Hard signs of PVI are overt and reliably define major AI, while soft signs merely raise the index of suspicion for possible PVI. Loss of pulses and active bleeding are the most frequent hard signs of AI found during PEX followed by expanding hematoma

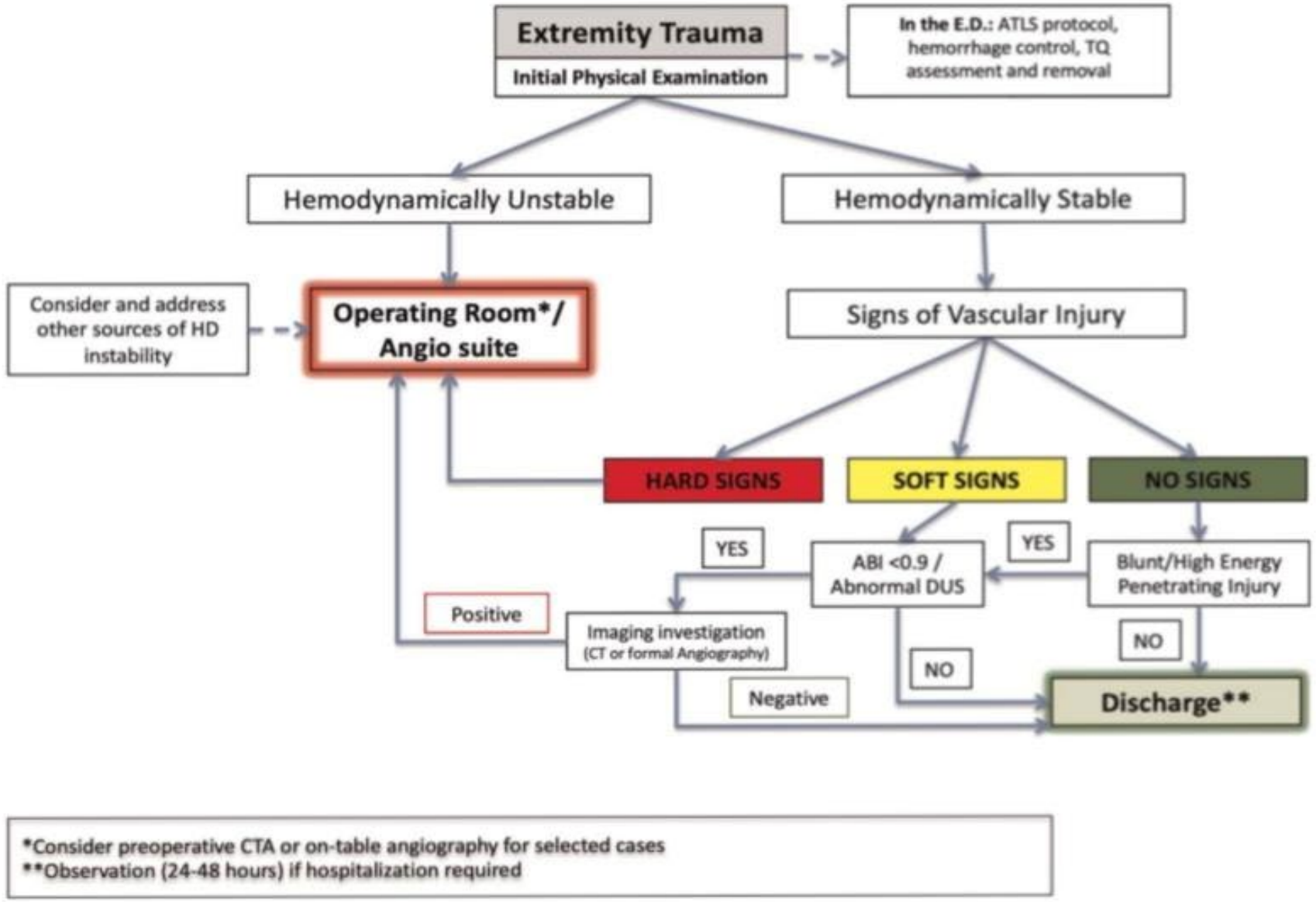

Figure 1. Peripheral vascular injury diagnostic and management algorithm.

- Nonexpanding and nonpulsatile hematoma is the most often encountered soft sign,(%35)
- Diminished pulse and external bleeding (20% each)

Diagnosis

- Conventional angiography
- Doppler ultrasonography
- CTA
- Magnetic resonance imaging (MRI)/magnetic resonance (MR) angiography

Doppler ultrasound

- Doppler ultrasound continues to have a role in screening for occult vascular injuries
- sensitivity and specificity of 95% and 98% in evaluating vascular penetrating extremity
- the experience and time needed to assess for PVI can be a limitation in the acute trauma setting.
- For extremity trauma, the FAST Doppler protocol (focused goal-directed Doppler procedure) has been proposed as a triage tool for both prehospital and in-hospital settings.
- this protocol cannot differentiate whether the pathologic flow is caused by an acute or a chronic lesion.
- Thus, in positive cases (presenting absent, monophasic, or biphasic waveforms at dorsalis pedis/fibular arteries), further immediate imaging evaluation is required

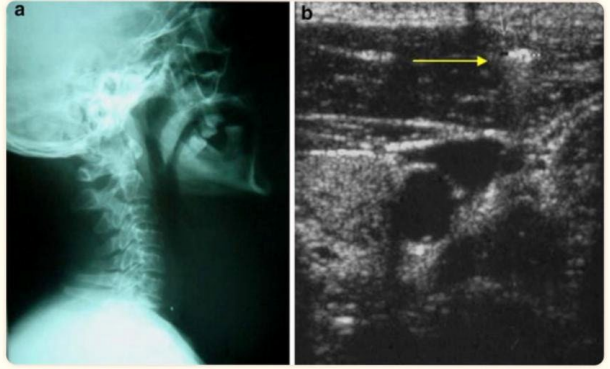

Fig. 2

No vascular compromise: B mode. **a** X ray showing a bullit in the base of the neck. **b** Mode showing the bullit in the esternocleido-mastoid muscle. No vascular compromise of the jugular vein nor the carotid artery

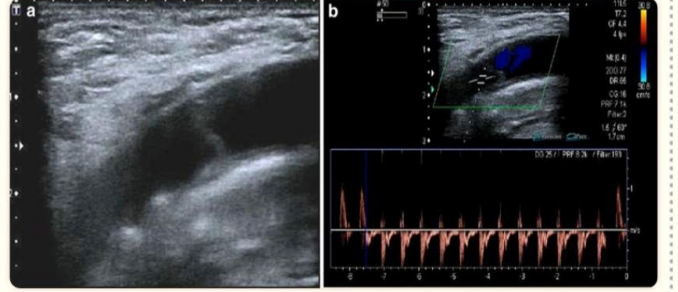

Fig. 11

Post traumatic femoral artery intimal flap. **a** B mode. Small echogenic flap into the lumen. **b** Turbulent flow with change of direction of the flow was seen moving the sample volume near the moving flap

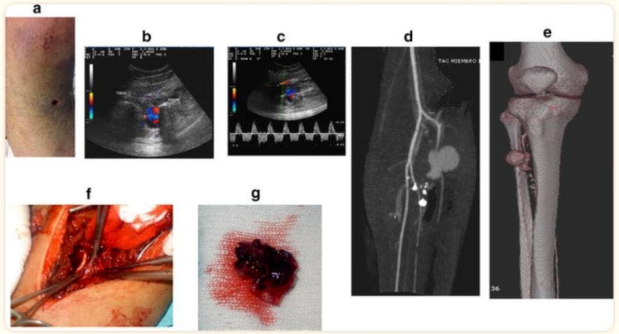

Fig. 16

Pseudoaneurism: Gun shot gun wound in the *right leg* with an arterial tibial pseudoaneurism. **a** Penetrating wound, **b** pseudo aneurism: color Doppler, **c** pulsed Doppler with the sample volume at the neck of the pseudoaneurism: bidirectional flow (to and fro), **d** CT angiography showing the pseudoaneurism and the metallic foreign bodies, **e** CT: 3D reconstruction, **f** surgical repairment, **g** intraoperative photography of the resected pseudoaneurysm

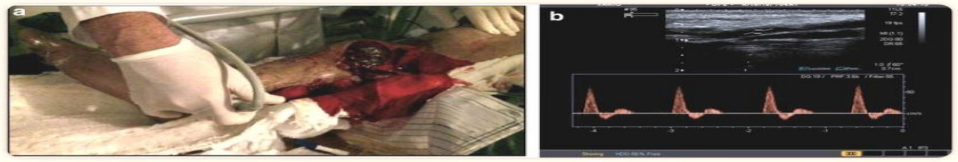

Fig. 19

Open fracture of the tibia. **a** Displaced long bone fracture with segment exposure. Exploration of distal pulses. **b** Normal triphasic flow

Montorfano MA, Pla F, Vera L, Cardillo O, Nigra SG, Montorfano LM. Point-of-care ultrasound and Doppler ultrasound evaluation of vascular injuries in penetrating and blunt trauma. Crit Ultrasound J. 2017 Dec;9(1):5. doi: 10.1186/s13089-017-0060-5. Epub 2017 Feb 16. PMID: 28211004; PMCID: PMC5313497.

Duplex US

- Reliable for
- – Injury to arteries and veins
- – A-V fistulas
- – Pseudoaneurysms
- – Thrombosis
- poorly accessible vessels :
- subclavian, profunda femoris, and profunda brachii arteries

Computed tomography angiography

- Sensitivity and specificity in identifying PVI exceed 90%
- Primary imaging tool for the assessment of PVI in the daily trauma center
- display of vascular injuries in the context of the surrounding tissues, especially the relationship to bones
- provide overviews of the vasculature that are partially comparable to angiography
- For upper extremity CTA, a venous access should preferably be placed in the noninjured arm, and ideally, the injured extremity should be raised above the head, decreasing beam-hardening artifact from the torso

- *Limitations:
- difficulty differentiating spasm from occlusion
- artifact from high attenuation structures like bullet
- fragments or other foreign matter

- signs of injury can be classified into direct or indirect.

Direct signs

- Relate to the vessel wall and often indicate significant VT that may require either surgical or endovascular repair
- include occlusion, thrombosis, intimal dissection, spasm, external compression, active arterial hemorrhage, and AVF .

Indirect signs

- Represent findings within the perivascular soft tissues such as
- perivascular hematoma
- a projectile tract near a neurovascular bundle
- shrapnel in a distance of <5 mm from a vessel .
- presence of indirect signs secondary to VT should raise suspicion for an occult injury

Indications for angiography

- Hemodynamic stability
- Uncertain diagnosis
  - Soft signs
  - PVD
- Unclear location
  - Multiple wounds, fractures
  - Shot gun wounds
  - GSW parallel to an artery

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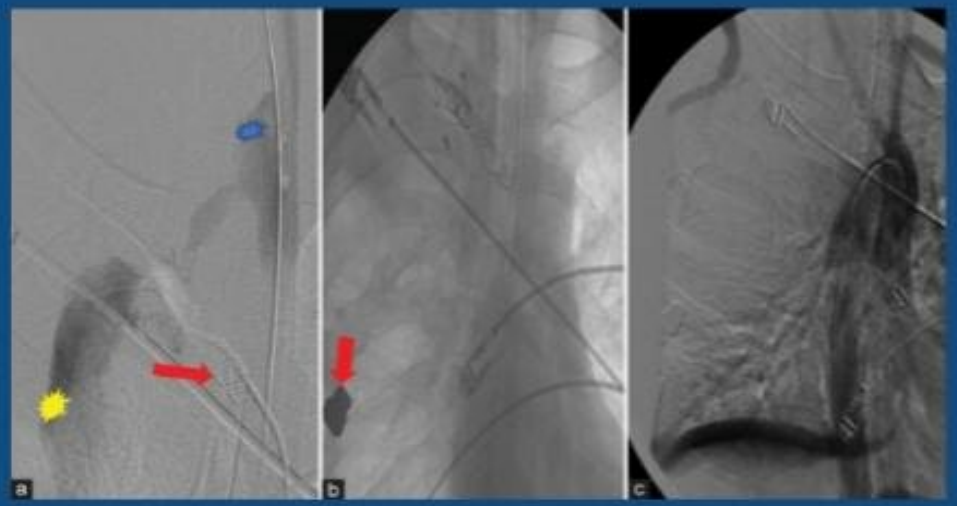

Figure 2: A 32-year-old patient with gunshot injury to the chest (a) selective angiogram of the aberrant RCA stump after surgical ligation for traumatic pseudoaneurysm shows active extravasations of contrast (Star) into the esophagus and right hemithorax and (b and c) post-endovascular coiling (Red arrow) of the stump shows closure of the leak. Notice migrated bullet in the right thoracic cavity.

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Figure 3: A 30-year-old patient presented with gunshot injury to the upper chest (a) angiogram is depicting a bullet (arrow) adjacent to an aberrant right subclavian artery in a patient with a transmediastinal bullet injury. (b) Contrast-enhanced axial computed tomography angiography demonstrates aberrant right subclavian artery coursing posterior to esophagus/trachea (c). Selective right subclavian angiograms show a wide neck 2 cm oval pseudoaneurysm measuring 6.0 × 3.5 cm in the distal 1/3 of the right aberrant subclavian artery on day.

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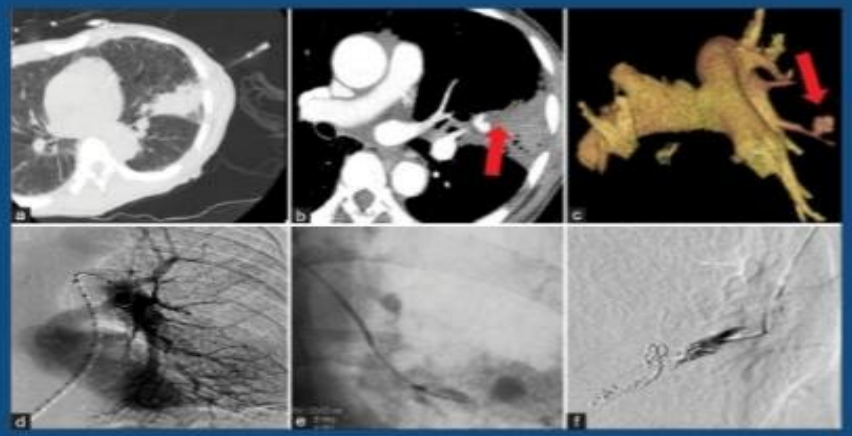

Figure 4: A 40-year-old patient with iatrogenic vascular trauma secondary to biopsy of consolidated lung (a) Contrast-enhanced CT demonstrating biopsy needle entering into the consolidated part of the lung. (b and c) Computed tomography angiography and 3D VR image showing a pseudoaneurysm (arrow) from a lingular branch of the left PA and (d-f) angiogram demonstrating pseudoaneurysm of the lingular branch of the left pulmonary artery and subsequent coiling.

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MRI and MR angiography

- The role of MRI and MR angiography in the setting of acute trauma is limited because of the practicalities of trauma patients in a MR scanner.
- In addition, a patient suffering from penetrating trauma may have retained metal fragments, which are noncompatible with MRI and may result in artifacts

Treatment of PVI

- Nonoperative management (NOM) can be considered in selected stable patients with AAST Grades I and II injuries without active hemorrhage or signs of distal ischemia. (GoR 2C)

- NOM can also be considered for isolated AAST Grade III tibial and peroneal injuries where either the anterior or posterior tibial artery remains intact and there is no active hemorrhage or distal ischemia. (GoR 2C)

- Nonocclusive injuries may be definitively managed nonoperatively based on four criteria:
- 5> mm intimal disruption
- adherent intimal flap
- intact distal circulation
- active hemorrhage

- These patients should be monitored closely, and any change in clinical examination should be followed by immediate repeat imaging, endovascular, or operative intervention

Operative Management of PVI

- In the presence of external hemorrhage, the use of direct pressure and tourniquets is recommended in the prehospital setting. (GoR 1C)
- Isolated radial or ulnar AIs without evidence of distal ischemia can be managed with simple ligation. (GoR 2C)
- Isolated infrageniculate AI where either the anterior or posterior tibial artery is intact and there is no distal ischemia can be managed with simple ligation, unless there is extensive soft tissue injury. (GoR 2C)

Operative Management of PVI

- Proximal and distal thrombectomy should be done with a Fogarty catheter for major AIs, and the proximal and distal segments should be flushed with heparinized saline. (GoR 1B)
- For AAST Grades IV and V injuries, tension-free end-to-end primary repair is the procedure of choice. (GoR 1C)
- Where primary repair is not technically possible, resection and interposition graft should be performed. When performing arterial reconstruction, autologous saphenous vein is the conduit of choice. (GoR 1C)

Operative Management of PVI

- For complex injuries and injuries with significant ischemic time, and in damage-control situations, intravascular shunts should be used to rapidly restore perfusion and bridge to definitive repair. (GoR 2C)
- Peripheral venous injuries should be repaired, if possible, to reduce the risk of amputation and venous insufficiency. (GoR 2C)
- In unstable patients and in those with destructive venous injuries not amenable to repair, ligation of peripheral veins is acceptable, but prophylactic fasciotomy or serial monitoring of compartment pressures should be considered particularly in combined arteriovenous injuries because of the high risk for compartment syndrome. (GoR 2C)

Operative Management of PVI

- Primary amputation may be considered in the unstable patient with a mangled extremity (Mangled Extremity Severity Score [MESS], >7) if presentation is significantly delayed (i.e., prolonged ischemic time with no sensation or motor activity) and in injuries with irreparable soft tissue damage leading to a functionally nonviable extremity. Optimally, this decision should be made by a multidisciplinary team. (GoR 2C)
- Endovascular repair may be considered in the management of peripheral PSAs, AVF, and other small vessel injuries diagnosed on CTAwithout hard signs of vascular injury. (GoR 2C)
- There is no evidence to support the use of systemic intraoperative heparinization or postoperative antiplatelet agents or anticoagulation after most vascular repairs. The exception is prolonged ischemic time with small vessel occlusions. (GoR 2C)

Prehospital Treatment of PVI

- The management of PVI begins before arrival to the trauma center
- tourniquets are a rapid, safe, effective, and lifesaving method for hemorrhage control
- waiting until trauma center arrival to apply a tourniquet is associated with:
- lower BP
- increased need for plasma transfusions
- a higher rate of transfusion within the first hour
- greater than 4.5-fold increase in mortality.

- Physicians now recommend that tourniquets be used when extremity hemorrhage presents a threat to life.
- tourniquets should be applied as soon as significant bleeding is noted or suspected, and application should not be delayed waiting for shock or arrival at a medical center

Operative Management of PVI Lower Extremity

- Simple nondestructive injuries are repaired, and complex injuries are either ligated or shunted.
- The contralateral extremity should be prepped and draped to facilitate saphenous vein harvest should more complex reconstruction of the injured extremity be required.
- Primary repair is the procedure of choice for isolated AIs with low-velocity penetrating wounds as long as a tension-free repair can be performed.
- If a damage-control approach is necessary, temporary intravascular shunt (TIVS) can be used to achieve temporary limb perfusion and allow delayed reconstruction.

- (PTFE) graft maintained structural integrity even in the face of staphylococcal infection with a low incidence of anastomotic disruption
- resist infection more than other prosthetic conduits such as Dacron
- PTFE and autologous vein had statistically equal graft complication rates

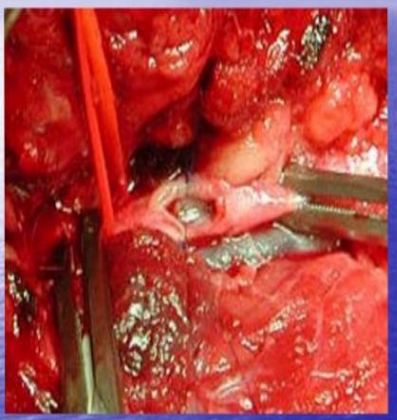
- There is much debate in the literature as to whether ligation or reconstruction should be the method of choice for complex lower extremity venous injuries.
- routine ligation claim that venous stasis is mitigated by collaterals, and multiple studies have demonstrated no permanent sequelae of venous ligation including no difference in amputation rates
- repair report acceptable patency rates and theoretical reduction in venous hypertension after repair
- ligation was significantly associated with increased rates of fasciotomy and secondary amputation

- In major popliteal injuries, primary amputation should be considered when there is :
- more than 6 hours of ischemic time
- disruption of the posterior tibial nerve
- Severe lower leg and foot wounds
- open comminuted fractures with segmental bone loss, multiple injuries in an unstable patient
- injuries requiring overwhelming extensive soft tissue coverage

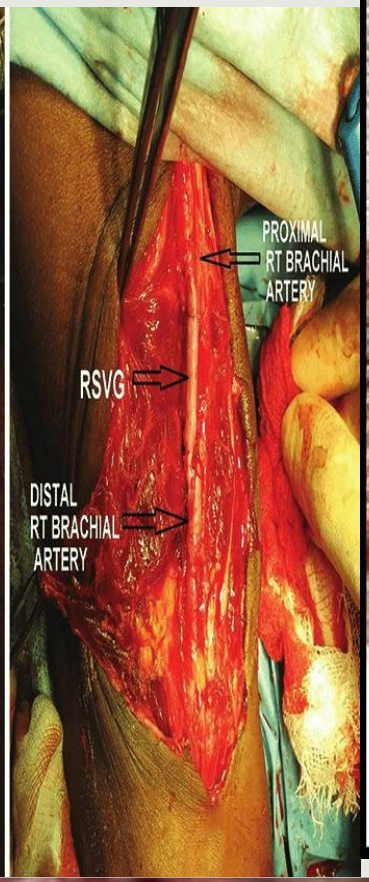
Upper Extremity

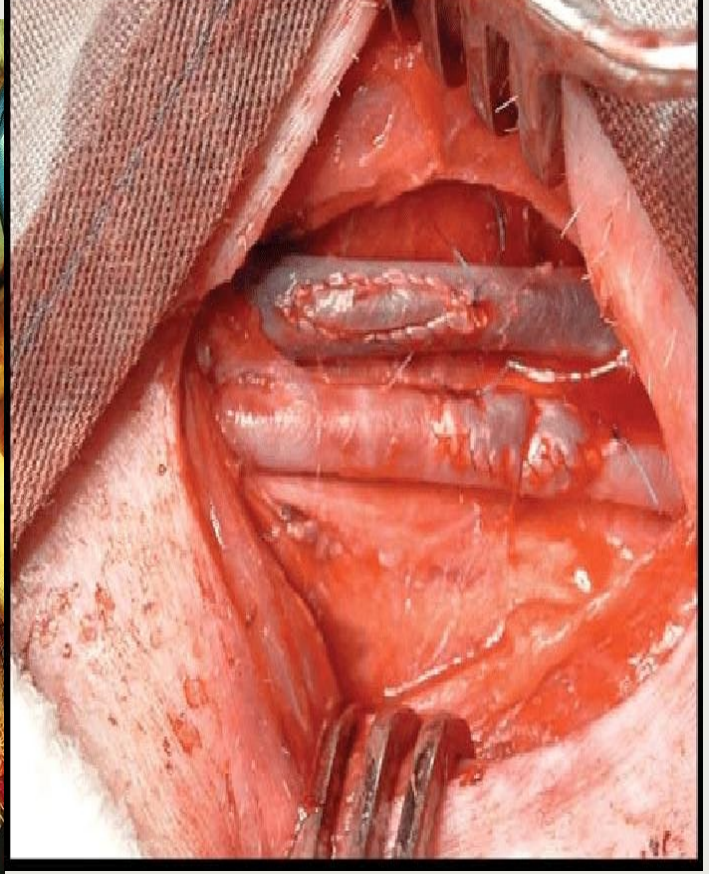
- Rapid access can be gained to the brachial vessels by making an incision along the medial groove of the biceps and triceps muscle.
- Techniques include:
- lateral suture
- patch angioplasty
- tension-free end-to-end anastomosis
- interposition graft.
- The majority of UEAIs can be repaired primarily with lateral arteriorrhaphy or resection with end-to-end anastomosis

Tension-free primary repair



Primary repair → defect < 1-2 cm





- Ischemic time is of critical importance for outcomes, and thus, it is generally recommended that vascular repair precedes orthopedic intervention
- Venous injuries in the upper extremity can generally be ligated because of the extensive collateral venous system

Perioperative Anticoagulation

- Multiple studies have shown that anticoagulation given to patients with traumatic AI without absolute contraindication has not been reported to increase the rate of bleeding complications
- failed to demonstrate any improvement in rates of thrombosis or amputation
- systemic anticoagulation given during an operation was not associated with improved graft patency or limb salvage but was associated with prolonged hospital stay and increased blood product use.

Endovascular Management

- Reviews of case reports and small case series have demonstrated the safety of endovascular repairs and generally favorable outcomes.
- However, early and late stent thrombosis has been reported, and long-term surveillance studies are lacking

Outcomes and Complication of PVI

- Patency rates of upper extremity PVI repairs are generally good, ranging from 93% to 97%
- While ischemic time does impact functional outcome, deficits appear to be more strongly associated with concomitant bony and nerve injury, and need for fasciotomy rather than type and timing of arterial repair

Outcomes and Complication of PVI

- Acceptable duration of total (tourniquet) and warm (no flow in a major artery) ischemia is considered to be limited by 2 and 6 hours, respectively
- negative association between duration of ischemia and rate of complications and/or limb salvage
- tourniquet dwell time of 60 minutes or longer was associated with more rhabdomyolysis, wound infection, and neurologic compromise.

Outcomes and Complication of PVI

- A greater than 6-hour interval between injury and revascularization has often been quoted as increasing risk for amputation
- Amputation for upper extremity PVI is much less common compared with lower extremity injuries and is associated with severity and location of PVI and associated injuries
- Brachial , popliteal and femoral artery artery carries the highest risk for amputation

Outcomes and Complication of PVI

- Compartment syndrome frequently complicates severe lower extremity injury and is associated with prolonged ischemia time (>4–6 hours) in patients with AI.
- Multiple reports have suggested the importance of prophylactic fasciotomy as opposed to waiting for symptoms to perform therapeutic fasciotomy


Any Questions?