Upper Extremity Vascular Injury

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Injury/Disease Demographics

- Penetrating trauma (stabbing and gunshots), suicide attempt, glass and window trauma, fractures, and industrial accidents are all common mechanisms and causes of injury to upper extremity vasculature.
- These injuries may present in the setting of other major and life-threatening trauma. The management strategy must focus on minimizing the duration of ischemia to maximize the chance of successful recovery and rehabilitation.

Clinical Presentation and Diagnosis

- Penetrating injury often presents with a history of either arterial hemorrhage or ongoing bleeding. A transected vessel can acutely clot however.
- Blunt injury usually causes thrombosis and signs of acute arterial occlusion with resultant ischemia.
- Significant neurologic injury, usually involving the median nerve, is present in 60% of patients with upper extremity arterial injury. Signs of median nerve injury include an inability to flex the wrist down, difficulty pronating, an inability to flex the thumb across the palm, and numbness and tingling of the first three fingers with associated weakness in grip. Documenting the patient's neurologic examination at presentation is crucial.
- Concomitant arterial and venous injury represents 20-40% of all vascular injury
- The diagnosis of upper extremity arterial injury is often made on physical exam alone. Findings may include:
    - pulselessness
    - pulsatile bleeding
    - obvious vascular thrill or bruit
    - cold, ischemic extremity
- An abnormal arterial pressure index, measured by the systolic pressure of the affected arm divided by the systolic pressure of the non-affected arm (A:A index), of less than 0.9 should increase the suspicion of an arterial injury.
- Patients with obvious arterial or venous laceration from penetrating trauma, in general, need to be taken directly to the operating room.
- Focal blunt force injury may also cause obvious injury, however, CTA is often used to confirm the diagnosis and plan therapy.
- Absent pulses in the presence of complex fractures or crush injuries of the upper extremity need to be assessed with CTA if normal perfusion does not return following resuscitation, fracture reduction, and the administration of adequate pain medications.
- Active hemorrhage from penetrating wounds should be controlled by direct pressure against bony structures with an experienced gloved hand. Bulky pressure dressings do not control hemorrhage and obscure the presence of ongoing bleeding.
- Tourniquets can control arterial hemorrhage but may compress venous outflow and increase bleeding.

Non-operative Management

- The widespread application of arteriography for the evaluation of extremity trauma results in the detection of clinically insignificant lesions. Non-operative therapy may be appropriate in patients with minor intimal irregularities without stenosis. However, in the upper extremity, most lesions require operative therapy.

Operative Techniques/Intraoperative Considerations

- In general, arterial injuries should be repaired whenever possible and reasonable in the overall orchestration of the patient's care. Simply stated, life over limb.
- Brachial artery ligation carries a high risk of subsequent amputation; intra-luminal temporary silastic shunts can be used to temporize the patient.
- The role of endovascular techniques in the relatively small brachial artery and forearm vessels is not established and they should not be used. Traditional operative exposure and repair remains the best approach to optimize results.
- Early involvement of an orthopedic surgeon or a plastic/reconstructive surgeon is an essential part of successful operative management given severe tissue loss in complicated injury.
- Pneumatic tourniquets should be sparing used and only placed and carefully monitored for adequacy of compression and duration of application. In general, they are not necessary.
- The patient should be widely prepped and draped with generous inclusion of the entire upper extremity, the shoulder, and the anterior-superior aspect of the chest to allow for incisions for proximal control. The upper extremity should be supported on two side-by-side arm boards or a hand surgery extension to the operating room table. The table should be positioned and the patient draped to allow members of the operating team to stand along the torso, at the hand and above the shoulder. The table should permit angiography. An uninjured leg should also be prepped and draped from inguinal region to toes to allow for saphenous vein harvest.
- The brachial artery is best exposed through a longitudinal incision along the medial aspect of the upper arm over the groove between the triceps and biceps muscles. The incision can be extended distally with an "S" shaped extension across the antecubital fossa from ulnar to radial aspect and onto the forearm to expose the origins of the forearm vessels.
- Axillary arterial exposure is obtained by making a transverse infra-clavicular incision over the delto-pectoral groove. A muscle splitting incision is carried down through the pectoralis major muscle. The pectoralis minor muscle is divided close to the coracoid process and the axillary artery and vein exposed where they traverse just below the plane of the muscle. There are cords of the brachial plexus, nerves to the pectoral muscles and large muscular branches of the artery in this area. Control of the artery should be carefully obtained and is safest with double passed silastic vessel loops. Balloon catheter

thrombectomy and flushing with heparinized saline followed by debridement of damaged arterial wall are essential to successful repair.

- Lacerated veins should be ligated unless there is extensive soft tissue and collateral vein injury and venous repair is required.
- Ischemia to reperfusion should be limited with a goal of restoration of flow as soon as possible. A duration of arterial occlusion and ischemia longer than 4 hours is of concern with limb loss likely at 6 hours. Temporary intra-luminal shunts (10 French Argyle™ or Pruitt-Inahara shunt) may be placed in the artery.
- Primary anastomosis of undamaged ends of vessel should only be performed if it can be accomplished tension-free. Saphenous vein interposition should be chosen whenever vessel injury is extensive or if primary tension-free repair is not possible. PTFE has a role in the upper extremity and can be used when autologous vein is not available.
- Forearm fasciotomy, particularly in the setting of ischemia greater than 4 hours or concomitant crush injury, should always be considered prior to completion of the operation.
    - The volar incision allows for decompression of the anterior compartment of the forearm. It is a curvilinear incision and should be carried down through the carpal tunnel.
    - The dorsal incision permits decompression of the posterior compartment and is a more linear incision.
    - Intra-operative compartment pressure measurements may provide decision-making data with an absolute pressure of greater than 25 mmHg concerning.
- There is a limited but important role for primary amputation in the management of upper extremity vascular injuries. Patients with extensive soft tissue loss with irreversible neurologic deficit, extensive fractures, and vascular injuries should be evaluated collaboratively with orthopedic and plastic surgery colleagues to determine if primary amputation is the best initial management.
- Combined ulnar and radial artery injury in the forearm require repair of at least one vessel. The ulnar artery is usually larger in the proximal forearm and is a better target for direct repair or saphenous vein bypass. Distally, the vessel repair should be performed in whichever vessel is largest or amenable to simple repair. Collateral flow should be evaluated. In this regard, Doppler flow is usually sufficient, however, angiography may be needed for confirmation.
- On-on table angiography is encouraged, but may not be needed in all instances. That being said, any concern for poor conduit, acute thrombosis or adequacy of flow should be evaluated by intra-operative angiography.
- Isolated ulnar or radial artery injuries can be managed with simple ligation only if there is absolute certainty that flow through the remaining vessel is adequate. Close inspection of the forearm and hand with palpation of pulses augmented by Doppler examination of the palmer arch is essential.
- Isolated forearm arterial injury should be repaired whenever possible and reasonable in the overall plan of care of the injured patients. This should never be done at the expense of more critical treatment priorities.

Postoperative Management

- Postoperative monitoring for patency of the vascular repair and the absence of upper extremity compartment syndrome is an essential part of successful management protocols.
    - Severe edema, and pain out of proportion to passive movement are early clinical indicators for compartment syndrome.
    - An absolute pressure of greater than 25 mmHg, as measured by needle pressure transduction, confirms the diagnosis.
- Early and prompt return to the operating room when thrombosis is suspected or compartment syndrome is diagnosed is the best way to insure successful limb salvage.
- There is no role for formal angiography to rule out suspected thrombosis of the vascular repair. Repeat operative exploration is the only way to successfully manage patients with concern for early thrombosis.
- There is no conclusive data on the role of anticoagulation or anti-platelet therapy after upper extremity vascular repair and therefore, outside of center specific inpatient DVT prophylaxis, post-operative heparinoid nor aspirin therapy is not administered.

Suggested Readings:

- Moore, W. Anatomy and Surgical Exposure of the Vascular System (44-67) and Vascular Trauma (721-754). In Vascular and Endovascular Surgery: A Comprehensive review. Eighth Edition. 2013.
- Rasmussen T, Tai N. Imaging for the Evaluation and Treatment of Vascular Trauma (44-55); Upper extremities and Junctional Zone Injuries (149-167). In Rich's Vascular Trauma. Third Edition. 2016.
- Carrick MM, Morrison CA, Pham HQ, et al. Modern management of traumatic subclavian artery injuries: a single institution's experience in the evolution of endovascular repair. Am J Surg. 2010;199(1):28-34.