Penetrating Cervical Vascular Injuries

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Objectives: At the completion of this module, fellows will be able to:

1. **Describe modalities used to effectively diagnose cervical vascular injury**
2. **Describe the operative techniques for vascular exposure of cervical vascular injury**
3. **Compare and contrast the treatment options for cervical vascular injuries**

Background

- The vast majority of penetrating cervical injuries are gunshot wounds (GSW) (75%) with stab wounds (SW) (20%) and other penetrating mechanisms (5%) account for the remainder.
- Overall, approximately 35% of GSWs and 20% of SWs to the neck result in significant injuries.
- Although transcervical GSWs cause significant injuries in 73% of victims, only 21% require surgery.
- The majority of vascular injuries involve the carotid artery, with only 10% of cervical arterial injuries involving the vertebral artery and vein.

Evaluation/Diagnostics

- The neck can be divided into three anatomic zones for the purpose of diagnostics and therapeutics:
  - Zone I (thoracic inlet)
  - Zone II (clavicles to angle of the mandible)
  - Zone III (between the angle of the mandible and the base of the skull).
- Overall, Zone II is the most commonly injured area (47%) in penetrating trauma, followed by zone III (19%) and I (18%). In 16% of patients, more than one zone is involved.
- Physical examination remains the most reliable initial diagnostic tool. The initial neurologic exam must be carefully documented.
- "Hard signs" of vascular injury that warrant emergent surgical intervention include:
  - Active arterial hemorrhage
  - Active venous hemorrhage
  - Absent carotid pulse
  - Expanding hematoma
  - Thrills/Bruits
- "Soft signs" of vascular injury detected on exam that mandate additional diagnostic imaging include:
  - Stable but significant hematoma
  - Pulse discrepancy on the affected side
  - Associated nerve deficit
  - Suspicious trajectory of injury to include penetration of the platysma
- Among patients with "soft signs" of injury, approximately 24% will have an angiographic abnormality – however, only 3-5% will require operation.

- Penetrating vertebral artery injuries may be initially asymptomatic and not actively bleeding due to thrombosis of the artery.
- Color flow Doppler may be useful in detecting cervical vascular injuries. This modality is operator-dependent, however, and may miss injuries in the proximal and distal neck (i.e. zones I and III) due to poor visualization with adjacent bony structures.
- In stable patients without hard signs of injury, CT Angiography (CTA) has replaced digital subtraction angiography (DSA). It has a documented sensitivity of 90%, specificity of 100%, positive predictive value of 100% and negative predictive value 98%.
- CTA interpretation may be more challenging when images are obscured due to artifact from metallic fragments or excessive air in the surrounding soft tissues. In these instances conventional digital subtraction angiography may be necessary to adequately identify or exclude vascular injury.
- When conventional angiography is performed for transcervical trajectories, all four cervical vessels should be interrogated.

Management

- The vast majority of penetrating injuries to the carotid artery require operative repair and/or reconstruction.
- It is important to secure the airway early in a patient's hospital course in the presence of an expanding hematoma.
- Optimal treatment of patients without hard signs of vascular injury who present with sustained coma or dense contralateral neurologic deficits is controversial.
    - Revascularization in this setting has the potential to produce a reperfusion injury with the development of significant cerebral edema, but some data suggests that rapid revascularization may support the best chance for neurologic improvement.
    - Patients with sustained stroke-related coma (>4 hours) have an extremely poor prognosis regardless of treatment.
- Angiographic embolization, balloon occlusion, angioplasty, and covered stents may be used as either temporizing bridges to surgical repair or for definitive treatment.
- Endovascular intervention should be carefully considered in patients with the following:
    - A distal internal carotid artery injury if hemodynamically stable.
    - An arteriovenous or carotid-cavernous sinus fistula.
    - Ongoing facial or intra-oral hemorrhage from external carotid branches.
    - Small intimal defects or pseudoaneuryms in surgically inaccessible locations or high-risk surgical candidates. Antiplatelet agents may be an alternative for these lesions; the risk/benefit of each therapy must be weighed.
    - Vertebral artery injuries with active extravasation.

Operative Technique

- Preoperative Considerations:
    - A towel roll is placed under the patient's shoulders.
    - The patient is placed on the operative table with neck extended and the head rotated away from the side of injury, if there are no contraindications. Penetrating

injuries to the neck generally result in stable fractures so contraindications are rare.
  - The majority of patients with penetrating trauma requiring a cervical exploration go directly to the operating room; the cervical spine is often cleared clinically if the patient is moving all extremities. Patients with known cervical spine fractures should be placed in a neutral position.
  - The patient should be prepped from the chin down to the knees in anticipation of the need for a median sternotomy or saphenous vein graft harvest.
- Exposure:
  - The incision of choice for exposure of the carotid artery is a longitudinal incision along the anterior border of the sternocleidomastoid muscle (SCM), from the angle of the mandible to the sternoclavicular joint.
  - Transection of the ansa cervicalis and division of the facial vein exposes the carotid bifurcation and allows mobilization and control of the internal and external carotids.
  - Rarely some zone I injuries may be controlled and repaired through a cervical incision, particularly if balloon occlusion has been employed as a temporizing measure. However the majority of zone I injuries require median sternotomy to control the origin of the carotid artery.
  - Identifying and dividing the omohyoid muscle allows access to the carotid sheath more proximally. The SCM is retracted laterally to expose the internal jugular vein.
  - The carotid artery is located medial and deep to the vein along with the vagus nerve. Zone III carotid injuries are the most difficult to expose and obtain distal control.
  - The cervical incision can be extended superiorly into the posterior auricular area and the digastric muscle is divided if more distal exposure is required. One must be diligent to avoid injury to the hypoglossal, glossopharyngeal, and facial nerves.
  - Anterior subluxation of the mandible improves exposure by converting a triangular space into a trapezoidal space. This is a difficult maneuver and is rarely required; if necessary, Otolaryngology or OMFS services are often utilized.

- Intervention:
  - Temporary control of uncontrolled zone I or III hemorrhage may be obtained by insertion of an embolectomy catheter through the existing arterial defect or by performing an arteriotomy; inflation of the balloon results in hemostasis. Shunting the defect may also control hemorrhage.
  - Most external carotid injuries may be ligated without consequence. Ligation of the common or internal carotid artery should be avoided as it can result in devastating neurologic sequelae if collateral circulation is inadequate through the circle of Willis.
  - Intravenous heparin should be administered if there are no other sites of hemorrhage or intracranial injury, preferably before clamping the artery.
  - Intraoperative heparin is dosed by one of two methods:
    i. Single systemic bolus of 5000 units

ii. Systemic bolus of 100 units/kg with a target ACT of 250; the ACT is rechecked one hour after administration to determine need for re-dosing

- Local irrigation with heparinized saline at the site of injury may be used.
- An intraluminal shunt (Argyle, Javid, or Pruitt-Inahara) may restore flow. This permits antegrade flow while additional injuries are evaluated/managed and/or vein harvesting is performed.
- Small lacerations may be primarily repaired using an interrupted 5-0 or 6-0 polypropylene sutures after adequate debridement of wound edges back to healthy intima.
- If primary repair is not possible, then an autogenous saphenous vein graft which is not reversed or prosthetic patch repair (Dacron or Bovine Pericardium) of the defect may be performed.
- The common carotid may be mobilized to facilitate a primary end to end repair; up to 2 cm of arterial loss (direct injury, excision of a pseudoaneurysm) may be reapproximated without the need for prosthetic.
- Autogenous non-reversed saphenous vein is preferred for internal carotid artery reconstruction, with some evidence of improved patency and lower infection rates compared to prosthetic graft. The saphenous vein should be harvested from the upper thigh as this segment rarely has valves. Utilization of a segment of saphenous vein without valves represents the only instance in which vein interposition conduits are not routinely reversed.
- Although described in the literature, reconstruction of the proximal internal carotid by transecting the proximal external carotid artery and transposing it to the distal transected internal carotid artery is rarely performed.
- Common carotid artery injuries are best repaired using a polytetrafluoroethylene graft (PTFE) or Dacron, which has a better size match with the native artery and excellent long-term patency. PTFE grafts may be ringed or plain. If the patient has an associated aerodigestive tract injury, autologous tissue (such as sternocleidomastoid muscle) is optimal over PTFE; the incidence of graft infections with PTFE, however, anecdotally appears to be rare.
- If associated injuries to the aerodigestive tract have been repaired, well-vascularized tissue such as a sternocleidomastoid muscle flap should always be interposed between the repairs, and closed system drain such as a Jackson-Pratt drain should be placed.
- If the injury or dissection extends into the distal internal carotid artery (zone III), exposure and repair are significantly more difficult. Ligation or catheter-assisted thrombosis of the injured vessel should be considered in the asymptomatic patient or if the appropriate expertise is not available to perform distal revascularization.
- If anatomically possible and feasible given patient condition, strong consideration should be given to repair encountered significant venous injuries (Internal Jugular vein).

Postoperative Management and Potential Complications

- New neurologic deficit noted after repair of a cervical vascular injury mandates emergent evaluation of the repair (OR versus CTA) and imaging of the brain to search for hemorrhagic stroke.
- The role of anti-coagulation or anti-platelet therapy after penetrating cervical vascular injury repair is individualized. If there are no contra-indications (intra-cerebral hemorrhage or active bleeding sites elsewhere), some elect to place the patient on aspirin therapy.
- Some routinely place patients on a systemic heparin or low molecular weight Dextran infusion during the first 24-72 hours.
- In the immediate post-operative period, the patient should be monitored in an ICU setting where neurovascular checks are performed hourly.
- Prophylactic antibiotics include one pre-operative dose.
- Although the optimal type and timing of surveillance after vascular repair is unknown, it is recommended that an individualized plan be developed and arrangements made to capture longitudinal follow-up following vascular repairs. Duplex ultrasound may be considered for amenable repair locations. For others, a follow up CTA at one to three months following repair is a reasonable approach.

Pearls from the Experts: Drs. Thomas H Cogbill and Ernest E. Moore

- If you do not perform elective carotid surgery, bring an anatomy book to the OR.
- Unless contradicted by concomitant intracranial or spinal injury or prolonged ischemic time, administer systemic heparinization ASAP. Heparin will not exacerbate bleeding, but thromboemboli can result in profound neurologic sequelae.
- Make an extensive incision for a suspected carotid injury, particularly for access to achieve proximal control.
- Apply digital control of bleeding until proximal vascular control is achieved.
- Back-bleed distally and flush with heparinized saline prior to clamping.
- If the facial vein is divided for exposure, identify the hypoglossal nerve.
- Identify the vagus nerve when encircling the carotid artery.
- Intravascular shunting of the common carotid artery is not necessary if the internal and external carotid arteries are intact.
- The Pruitt-Inahara shunt is the optimal shunt for small vessels as the smaller outside diameter is less likely to cause intimal disruption. Furthermore, it is useful for distal injuries in which circumferential arterial dissection above the injury is not able to be achieved. In these cases, the Pruitt-Inahara shunt allows distal control by virtue of intra-vascular balloon inflation. In addition, a distal arteriogram can be performed through the shunt side port. The side port may also be flushed intermittently to confirm patency.
- Internal carotid artery shunting should be done routinely because associated shock may exaggerate the risk of ischemia.
- The distal internal carotid artery must be transected at the level of normal vessel wall to avoid sub intimal dissection.

- For the scenario of poor back pressure in the distal internal carotid artery, the proximal and distal anastomosis should be performed with a stent in place as much as possible.
- Do not forget- saphenous vein interposition graft is non-reversed.
- Following vascular reconstruction, one must exclude the presence of an esophageal injury.
- For exploration of Zone II neck vascular injuries, an anterior sternocleidomastoid incision is preferred as it can be extended for more distal and proximal injuries. The sternocleidomastoid incision can be combined with median sternotomy for excellent exposure of the innominate artery as well as the proximal common carotid artery.
- Large hematomas can significantly distort anatomy. If the sternocleidomastoid muscle is not easily visible, an incision should be placed along a line between the ipsilateral edge of the sternal notch to the mastoid process. Find and stick to familiar landmarks at each level of dissection- a) platysma muscle, b) anterior border of the sternocleidomastoid muscle, c) anterior edge of internal jugular vein with ligation and division of the common facial vein, d) common carotid, internal carotid, and external carotid arteries.
- If arterial hemorrhage is encountered as the hematoma is entered, temporary vascular control is often best achieved by simple digital pressure control while dissection is accomplished to visualize the arterial injury. This method is safer and more effective than blind clamping in an attempt to achieve vascular control.
- Hypoglossal nerve injury is best avoided by beginning arterial dissection on the common carotid artery and dissecting in a cephalad direction along the posterolateral edge of the internal carotid artery. The hypoglossal nerve drapes across the internal carotid and external carotid arteries above the carotid bifurcation; it is most inferiorly located atop the external carotid artery and more superiorly located atop the internal carotid artery.
- Vagus nerve injury is best avoided by careful circumferential dissection of the common carotid artery followed by placement of a silastic vascular loop. The vascular loop is used to assist in clamp placement under direct vision so as to avoid catching the vagus nerve in the tips of the vascular clamp.
- Use of the long Sundt silastic intravascular shunt allows for optimal visibility during repair as it can be moved out of the way while maintaining good flow.
- Immediately after any intravascular shunt placement, adequate distal arterial flow should be confirmed using a hand-held Doppler.
- A penetrating wound to a portion of the carotid artery with significant pre-existing arteriosclerotic plaque may require endarterectomy or resection of the involved segment with interposition graft placement for a successful repair. Attempting simple repair in these circumstances is likely to result in early thrombosis.
- Proximal common carotid artery injuries may be best managed by transection of the vessel at the site of injury, proximal ligation using running 4-0 polypropylene suture and either direct anastomosis of the distal end of the common carotid artery to the side of the subclavian artery (transposition). Alternatively, this can be accomplished with placement of an interposition graft from the side of the subclavian artery to the distal end of the common carotid artery.
- Proximal left common carotid injuries may have an associated thoracic duct injury. An effort should be made to locate and ligate the thoracic duct with permanent polypropylene suture to prevent a significant lymphatic leak.

- For distal internal carotid arterial injuries at the skull base where operative exposure and repair are not possible, proximal ligation or endovascular detachable balloon occlusion are recommended for hemorrhage control. Ligation/occlusion should be avoided in the presence of hypotension to prevent ischemic stroke from inadequate collateral cerebral perfusion.
- A sterile, hand-held ultrasound probe may be used after arterial repair to interrogate the repair site for any intimal disruption, flaps, thrombus, or resultant stenosis that should be corrected before wound closure. These defects may be seen on real-time ultrasound imaging. Significant (>3 mm) flaps or thrombus mandate re-exploration and correction. In addition, calculation of peak systolic velocity (PSV) at several intraluminal locations can be used to determine degree of residual stenosis. PSV> 200cm/sec is associated with >70% stenosis. Residual stenosis of >70% at the repair site usually requires resection of the stenotic portion and either primary re-anastomosis or interposition grafting.
- Most vertebral artery injuries are not amenable to open repair. Endovascular techniques are best used for control of hemorrhage.
- Occasionally, proximal vertebral artery injuries may be managed by open repair using an interposition vein graft or proximal ligation and transposition of the distal end of the vertebral artery into the side of the common carotid artery. These procedures may be accomplished via a transverse supraclavicular incision with dissection of the scalene fat pad medial to the anterior scalene muscle. Care must be taken to avoid injury of the phrenic nerve. The thoracic duct should be divided and ligated with permanent polypropylene suture for left sided injuries.
- After repair of carotid artery injury from a shotgun wound, a repeat arteriogram is recommended 5 to 10 days after repair to avoid missing another arterial injury at a different location with resultant late pseudoaneurysm formation.

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