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Interventional radiology for vascular injuries of the neck and face

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an Vascular injuries in the face and neck are among the most complicated situations to confront the interventional radiologist. The diagnostic workups can be very complicated, time-consuming and highly variable because of the large number of anatomical structures contained within the confines of the platysma muscle. The complications associated with missed injuries or inappropriate therapies may be life-threatening. The vasculature of the brain is vulnerable; disruptions of the aerodigestive systems provide a source of infections by virulent organisms.

Airway management is central to the successful management of these patients. Liberal use of endotracheal intubation is recommended. It is always safer to have an airway before transporting the patient to the Invasive Radiology suite rather than be forced to do it in the radiology department. External bleeding must be stopped before imaging can be considered. Neurological damage is a common sequelae of neck trauma.

Most arteriograms and radiological interventions for cervicofacial injuries are performed in patients who have sustained penetrating trauma from knives, gunshots and accidental perforations. Blunt injuries usually do not present such a difficulty for the traumatologist because bleeding is self-limiting. However massive facial injuries, especially those of the midface LeFort type fractures, may cause epistaxis. This is often controlled by packing of the wounds. If persistent bleeding occurs, angiography is often indicated to control the bleeding. An uncommon blunt vascular trauma is carotid-cavernous fistulas associated with basal skull fractures. Another injury sometimes seen by radiologists is a stretch injury of the vertebral artery or internal carotid artery caused by hyperextension of the neck. This injury usually results in intimal damage rather than complete transection of the vessel. However, when transection occurs, interventional radiology provides an alternative treatment to control hemorrhage.

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Imaging strategy

The indications for angiography in neck trauma are determined by the clinical presentation and degree of hemodynamic stability and the Zone of the penetration. Zone I is defined as the lower neck at the thoracic inlet. It extends from the level of the cricoid cartilage to the thoracic inlet. Zone II is the mid neck and extends from the cricoid cartilage to the edge of the mandible. Zone III is the high neck and extends from the edge of the mandible to the skull base.

Zone I penetrations warrant arteriography only when the patient is hemodynamically stabilized. All such studies should be performed urgently because decompression of an arterial injury into the pleura or mediastinum can result in immediate exsanguination. Penetrations of Zone II can undergo operative exploration without arteriography if there are "hard signs" of vascular injury such as expanding hematoma, external blood loss or central neurological deficit because of the rapidity and safety of exploration of the carotid sheath. Zone III wounds, including those with "hard signs" of vascular injury, are usually best managed by angiography because of the difficulties in obtaining operative adequate exposure and vascular control. Clinical differentiation of the various causes of bleeding in Zone III and the face, including the internal carotid artery, the external carotid artery and its branches or the vertebral artery, can be very difficult for the traumatologist. Operative control of these bleeding sites may take a long time and also be relatively ineffective. Internal carotid or external carotid

ligation can have disastrous consequences.

Zone I injuries can often be completed by thoracic aortography which will visualize the origins of the brachiocephalic arteries, as well as other potential injuries at the base of the neck, such as the vertebral, internal mammary and other branches of the subclavian arteries. Aortography may be sufficient for lower penetrations of Zone II but most higher injuries above the cricoid cartilage require selective carotid and vertebral catheterization. Zone III injuries always require selective catheterization because these wounds are always difficult to visualize.

Control of hemorrhage and arteriovenous fistulas of specific vascular injuries

Brachiocephalic vessels:

There is practically no role for embolizatin of the subclavian artery, the innominate artery or the common carotid arteries because these vessels are not expendable and efforts to repair them should be made in almost all circumstances. The interventional techniques applicable in these vessels are covered stents and temporary balloon occlusion. Temporary balloon occlusion techniques may allow preoperative vascular control prior to operative repair. Covered stents are currently investigational but offer advantages such as avoidance of sternotomy for the management of these large vessels. The branches of the subclavian artery, such as the vertebral artery, the costocervical trunk and the thyrocervical trunk are expendable because of a rich collateral network; embolotherapy should be considered the primary method of hemostasis.

Embolization is the treatment of choice for most transmural injuries of the vertebral artery. The vessel is expendable because of dual supply of the basilar artery occurs in about 93% of patients. Moreover, ligation is usually the treatment during operative management. The ability to provide the same end result without the blood loss, without the surgical risks to adjacent structures are good reasons to attempt nonr operative therapy.

Internal carotid artery

Injuries of the internal carotid artery are among the most challenging wounds facing traumatologist, vascular surgeons and interventional radiologists. Death rates greater than 20% have been reported. There are few vascular injuries which are more dramatic in presentation. Massive hemorrhage from the ear, the mouth, the nose or throat may be present on admission. Aspiration of blood may cause respiratory compromise. Total control of external hemorrhage may be impossible. Packing of nose, neck or throat may be necessary to slow hemorrhage sufficiently to allow arteriography. Direct operative control without the availability or opportunity for mapping and diagnostic arteriography is highly undesirable. The surgeon often finds it difficult to identify the source of hemorrhage and to differentiate internal carotid, jugular and external carotid hemorrhage.

Operative exploration, control of hemorrhage and restoration of prograde cerebral arterial flow, with some exceptions, are the optimum treatment of most internal carotid arterial injuries. However this is usually not possible because of associated injuries, the inaccessible location of the wound, or because the patient has been in prolonged coma. Two methods of radiological intervention, including transcatheter arterial coil embolization and temporary balloon occlusion, are routinely used in the management of these injuries. Embolization of the injured ICA is appropriate in several circumstances: 1. if the location of the injury is considered by the trauma surgeon to be inaccessible to operative repair; 2. transection of the internal carotid artery above the angle of the mandible with poorly controlled bleeding or arteriovenous fistula from the proximal vessel and no prograde intracranial flow; 3. prolonged coma; 4. thrombosis of the ICA which has propagated into the petrous and cavernous portions of the carotid. The decision to coil embolize a patient who has an nonr occlusive ICA injury is more difficult. The ideal treatment is restoration of flow-not the termination of flow. Many of the injuries which are not accessible should be observed before resorting to embolization. If follow-up imaging shows deterioration in the angiographic appearance, coil occlusion should be considered only after provocative testing by temporary balloon occlusion demonstrates that the patient can tolerate embolization. The technique is as follows:

The patient is kept alert and awake during the procedure. Angiography of both carotid arteries and the vertebral artery are performed to determine the completeness of the Circle of Willis. The patient is anticoagulated with heparin. Then an occlusion balloon catheter is placed in the internal carotid artery

and inflated to occlude flow to the brain. The balloon is left inflated for 30 minutes and the patient is constantly assessed for neurological deficits such as slurred speech, weakness or diminshed sensation. If neurological problems occur, the balloon is immediately deflated: the patient has failed testing. Neurological deficits usually resolve immediately after return of blood flow. If no deficits occur, the vessel is occluded permanently by coils in the internal carotid artery. This author has used steel coils exclusively for embolization of the ICA. Embolization should be performed after arresting prograde flow by temporary balloon occlusion. Coils can be delivered coaxially through the end hole of an inflated balloon catheter with less risk of clot embolization during coiling. When thrombosis has occurred, proximal embolization alone is recommended. Preoperative temporary balloon occlusion should be considered when active bleeding is identified on arteriography from a portion of the ICA that is believed by the surgeon to be accessible to repair. Balloon angioplasty can also be used when intimal flaps have formed after injury to the ICA. These may heal spontaneously but may also result in pseudoaneurysm, embolization or occlusion. The augmentation of angioplasty by the placement of an expandable stent can be considered. Covered stents are a new and investigational technique which can heal the injury while maintaining flow. It may become the procedure of choice in the future. However, only a few cases have been reported to date. Emboli are a major contributor to the poor outcome in some patients with ICA injury. The recent favorable reports of the use of thrombolytic agents in the treatment of strokes suggests that this technique may have considerable value in modifying the outcome of some patients with ICA injuries. It may be possible to lyse these emboli and reverse the neurological deficits of this injury and improve the survival rate.

Carotid cavernous arteriovenous fistula (CCF) are direct high flow communications between the cavernous portion of the internal carotid artery and the cavernous sinus. They are often the result of blunt trauma and may be associated with severe facial fractures, Pulsating tinnitus, headaches, exophthalmus, proptosis and chemosis are the major complaints. The treatment of choice for these lesions is transcatheter depolyment of detachable balloons or coils within the cavernous sinus in a way that allow internal carotid arterial flow to be maintained. Balloon placement within the cavernous sinus from a transarterial route is successful in most patients. In the remainder of patients a transvenous approach to the superior orbital vein via the inferior petrosal vein can be used to gain access into the cavernous sinus.

External carotid artery

External carotid artery (ECA) trauma is often associated with internal carotid arterial injuries but may also be an isolated wound. The clinical presentations are similar to and as varied as ICA injury. Physical findings do not correlate with the presence and extend of damage. The close proximity to the jugular vein and the numerous venous structures draining the neck and face also predisposes to arteriovenous fistulæ. The ECA is expendable in most young trauma patients and ECA injury is best managed by embolization as this will obviate the need for exploration in many patients and avoid additional blood loss of operative repair. Because the ECA is a large conduit vessel, it should be treated like other large vessel injuries by isolation of the damaged segment. Proximal and distal embolization with coils are necessary as the extensive collateral network in the face will allow hemorrhage to recur if only the proximal end of the vessel is occluded.

Although the branches of the external carotid artery are small vessels, they can bleed profusely or develop large hematomas. Shock or exsanguinating hemorrhage from the mouth, nose, orbits and scalp may occur. Selective external carotid catheterization is necessary to delineate adequately injuries to these vessels.

Injuries to the superior thyroid artery can be treated by embolization provided selective catheterization and a solid firm engagement of the orifice of this vessel can be accomplished. Dislodgment may result in intracranial embolization. Microcatheterization may be warranted to obtain good purchase within the vessel.

Lingual artery injuries may bleed profusely and aspiration may complicate the situation. Lingual edema may also compromise the airway and should be carefully observed during arteriography. Emergency suturing of the laceration may control hemorrhage and this should be attempted before arteriography when technically feasible. In some cases manual compression of the tongue will slow the bleeding sufficiently to allow arteriography to proceed. Particulate em-

bolization is warranted for most of these patients. Microcatheter techniques are recommended as they provide an added margin of safety by allowing more distal catheterization which spares the normal vasculature of the tongue and limits the area of ischemia and infarction.

Facial artery bleeding often results in large but superficial hematomas of the cheek, lower orbit and mandible. Peripheral branch injuries are best treated by flow directed pledget embolization while lacerations of the proximal portions of the vessel are best treated by proximal and distal large vessel occlusion with coils. Transections can be problematic, especially if associated with distal arteriovenous fistula. This vessel is quite tortuous and catheterization of the distal end of the severed vessel from the proximal segment may be difficult or impossible. Observation and follow up arteriography may be a reasonable technique when distal occlusion is impossible. The distal end of the vessel may spontaneously occlude. When AVF is present, the distal vessel will hypertrophy. It may become palpable and amenable to percutaneous catheterization and embolization.

The ascending pharyngeal artery is a small, slender vessel which originates near the origin of the ECA and extends to the base of the skull. When it is injured, it commonly thromboses. Significant bleeding is rarely a problem. It is an expendable vessel which could be treated by particulate embolization with gelfoam.

The occipital artery contributes greatly to the vascularity of the scalp and supplies neck muscles, the ear, the dura and cranial nerves. The close proximity of the artery to the numerous venous structures in the scalp predispose to the development of arteriovenous fistulas. The occipital vessel is an expendable vessel and the treatment of choice is transcatheter embolization. Proximal and distal isolation of the injured segment are usually necessary as the rich vasculature of the scalp allows collateral filling of the vessel from vertebral artery branches to the muscles of the back of the neck, the ascending cervical branch of the thyrocervical trunk, the contralateral external occipital artery and the superficial temporal and the posterior auricular arteries. Small particulate embolization is the preferred technique for small branch injuries because they can be flow directed into the periphery when the catheter cannot be placed close to the arterial injury. AVF require proximal and distal coil occlusion.

The internal maxillary artery is expendable and can be embolized when injury is diagnosed. Particulate embolization with gelfoam pledgets of 1– 2 mm cubes will be directed by flow to the bleeding terminal vessels. Large vessel occlusion with coils is rarely necessary.

Injury to the superficial temporal artery is similar to that to the occipital artery. The treatment of these injuries is initially surgical with suture closure of the scalp laceration and ligation of bleeders. This may be sufficient to arrest hemorrhage. However, arteriovenous fistulas and false aneurysms may be obscured by the scalp hematoma. Moreover, if ligatures are not placed proximal and distal to the injury, AVF may persist through collateral circulation. The rich vascularity of the scalp makes treatment of chronic AVF of the scalp very challenging. The STA is normally very tortuous and this may be amplified by the increased blood flow asociated with chronic AVF. The numerous connections to other branches of the STA as well as branches of the occipital artery and the facial artery make proximal occlusion virtually useless with rapid recruitment of other vessels if the proximal inflow from the STA is occluded. Percutaneous puncture of the fistula often facilitates closure of these fistulas. Coils or balloons are the embolic materials of choice in these cases. Occlusion of the damaged arteries as they enter the fistula is the goal of the treatment, although embolization of the false aneurysm without embolization of the arteries feeding the AVF has been described.

In summary lnterventional radiology plays a critical role in the management of traumatic hemorrhage in the neck and face. It has become the primary method of controlling bleeding from many of these injuries. Close cooperative teamwork with the traumatologist is vital to the successful application of embolization for these patients.