Blunt Traumatic Aortic Injuries

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Injury/Disease Demographics

- Blunt traumatic aortic injury (BTAI) is a leading cause of death following blunt trauma; historically more than 80% of patients with BTAI died at the scene.
- The most common location of BTAI is in the descending thoracic aorta, just distal to the left subclavian artery. Other locations include the root of the aorta and the aorta just above the diaphragm.
- The mechanism of injury is a sudden deceleration that often results after motor vehicle crashes (including motorcycle crashes and pedestrians struck by a vehicle) or falls.
- Most patients are men.
- All ages are at risk of injury; BTAI is more commonly seen in adults, with a reported 0.1% incidence in children.
- Congenital aortic anomalies such as a bovine aortic arch and an aberrant right subclavian artery are more often identified in patients with aortic injury than in the general population.
- Associated injuries are common and often include concomitant head injury, pelvic fracture, long bone fractures, and / or intra-abdominal injury requiring an exploratory laparotomy.

Clinical Presentation

- Patients arriving to the hospital present in a highly variable manner ranging from hemodynamically stable to hypotensive in extremis.
- BTAI is not always the most life threatening injury. Hypotension is often not the result of an aortic injury but due to associated injuries.
- Patients presenting in extremis due to a ruptured descending thoracic aortic injury are very challenging to treat and their attempted repair is associated with an exceedingly high mortality rate.

Diagnostics/Imaging

- Chest radiograph is the traditional screening test that can identify features concerning for BTAI:
    - widened mediastinum $\geq$8cm
    - blurred aortopulmonary window
    - loss of aortic knob
    - rightward tracheal shift
    - apical cap
    - depressed left main stem bronchus > 110°
    - deviated nasogastric tube, if present
- Chest radiography has a low sensitivity and limited specificity secondary to suboptimal positioning because the patient is supine and it is an anteroposterior radiograph:

    - only a small percentage of patients with a widened mediastinum have BTAI.
    - up to 10% of patients with a normal chest radiograph are ultimately diagnosed with BTAI.
- CT angiography (CTA) scanning has become the routine screening and diagnostic study for BTAI with:
    - A 100% sensitivity and 99.7% specificity and an 89% positive and 100% negative predictive value.
    - Provides key information for the pre-operative planning of an endovascular repair including aortic diameter, detailed proximity of the arch vessels and landing zones in relation to the site of injury.
    - Identify the presence and extent of secondary signs of BTAI such as mediastinal hematoma.
    - Can diagnose additional thoracic injuries.

<u>Evaluation and Assessment</u>

- Improved imaging technology has led to the increased diagnosis and appreciation of a wide variability of BTAI severity. The spectrum ranges from small intimal injury to pseudoaneurysm up to frank rupture with extravasation (see grading scale below).
- Size of pseudoaneurysm, the presence of secondary signs of injury such as large mediastinal hematoma can be used with serum lactate to help identify patients who require emergent treatment.
    - A case of frank rupture would mandate a high risk emergent repair
    - A large pseudoaneurysm in conjunction with one of the secondary signs of injury should be urgently repaired
    - A risk score to predict early rupture was recently proposed and identified various factors including size of pseudoaneurysm, extent of mediastinal hematoma, and serum lactate level as the critical variables (see below). Presence of any two of three variables is also considered high risk for aortic rupture
- With appropriate β-blocker therapy to reduce the dP/dT and shear force along the lumen wall, small pseudoaneurysms have a low risk of rupture.
    - Esmolol is the first line treatment due to its rapid onset and short half-life.
    - Hemodynamic goals are for a systolic blood pressure between 100-120 mmHg, and mean arterial pressure less than 80 mmHg, and a heart rate between 60 and 80 beats per minute.
- Most patients that develop frank rupture do so with in the first 8 hours after injury; there has been no report of an aortic rupture in a patient treated with appropriate β-blocker therapy.
- BTAI is often not isolated; other life threatening injuries may be present whose treatment take priority over a concomitant aortic injury.

Summary of BTAI Grading Scales

Lesion	SVS	Stanford	Presley	Vancouver	Shock Trauma	Harborview
Isolated mediastinal hematoma (MH)			I			
Intraluminal defect		I				
Intimal injury	I	II	IIa	I < 1cm	I	I
			IIb with MH	II > 1cm		
Mural hematoma	II	III			I	
Pseudoaneurysm	III	IV: < 50% circumference	IIa: < 1cm IIb:< 1cm+MH	III	II:< 50% circumference	II
		V: > 50% circumference	IIIa: > 1cm IIIb:> 1cm &proximal to LSCA		III: >50% circumference	
Rupture	IV		IV	IV	IV	

Risk Factors Associated with Rupture of BTAI

Study	Admission Physiology	Pseudoaneurysm Size	Mediastinal Findings
Rabin	N/A	> 50% aortic circumference	Hematoma with mass effect, aortic pseudocoarctation, or large left hemothorax
Harris	Lactate >4 mM	> 1.4x normal aortic diameter	>10mm hematoma at posterior descending aorta

Role of Conservative Management and Associated Considerations

- Medical management with heart rate and blood pressure control was originally intended to support a strategy of delayed open repair that would reduce the risk of peri-operative bleeding and decrease the excessively high morbidity and mortality associated with emergent repair.
- Delayed repair (>24 hours after injury) is now a routine strategy that is associated with improved results especially in patients with concomitant traumatic brain injury.

- Many low grade intimal injuries frequently resolve, small pseudoaneurysms rarely rupture, and rupture of large pseudoaneurysms is also uncommon in patients started on appropriate β-blocker therapy. For patients managed non-operatively, repeat imaging is often performed at 7 days to insure injury stability or resolution.

Indications for Operative Intervention

- Emergent repair is required for cases with evidence:
  - frank rupture
  - high grade pseudoaneurysms (pseudoaneurysm > 50 % circumference or > 1.4 times normal aortic diameter) with associated signs concerning for aortic instability such as significant mediastinal hematoma, large left hemothorax, aortic pseudo-coarctation, or elevated serum lactate (> 4 mmol) which place the patient at high risk of rupture.
- High grade pseudoaneurysms alone are often amenable to delayed repair after initial treatment with heart rate and blood pressure control.
- Patients who have small pseudoaneurysms and high risk associated signs of injury or cannot tolerate heart rate control with beta blockers may require a lower threshold for surgical intervention.
- Intimal injuries and small pseudoaneurysms can often be successfully treated with medical management alone and serial imaging. Lesions that show concerning progression on follow up imaging should be repaired.

Pre-operative Preparation

- Initial treatment for all cases of aortic injury includes the administration of β-blocker to reduce the blood pressure and aortic wall shear stress (dP/dT). For patients with heart rates < 60 bpm, initial therapy with nicardipine or other antihypertensive agents may be appropriate. For patients whose blood pressure cannot be controlled with esmolol alone, additional agents may be necessary. Of note, starting a vasodilator may result in reflex tachycardia.
- These medications are titrated to achieve a systolic blood pressure goal of 100-120 mmHg and a heart rate ranging between 60-80 beats per minute.
- Careful assessment of the patient's vascular injury anatomy is necessary for appropriate planning of an endovascular repair. Arch vessel configuration and their proximity to potential landing zones and injury site help with the pre-operative planning. Finally the peripheral vasculature, aortic curvature, and aortic diameter help determine the appropriate device to deploy and endovascular access sites.

Impact of Associated Injuries

- Other surgical procedures may take precedence over management of the BTAI such as a laparotomy to control intra-abdominal bleeding.

- In patients with BTAI and concomitant TBI, early repair (with in the first 24 hours) is associated with worsening TBI and maintaining cerebral perfusion pressure of at least 55 mmHg is often compatible with the hemodynamic goals for BTAI management.
- Patients with hypoplastic, injured, or occluded right vertebral arteries should be considered for carotid-subclavian bypass prior to stent placement if the TEVAR is planned to cover the left subclavian artery.

<u>Operative Techniques / Intra-operative Considerations</u>

Open Repair

- When open surgical repair is performed it is via a posterolateral thoracotomy and often reconstructs the injured aorta with an interposition graft. There are 3 options:
    - While the simplest technique is "clamp and sew" it is associated with an increased risk of paraplegia.
        - Proximal and distal control of the aortic arch and distal aorta are obtained followed by exploration of the mediastinal hematoma.
            - The proximal clamp may be positioned either distal to the left subclavian artery or between the left subclavian and left common carotid artery.
        - The injury may be either primarily repaired or reconstructed with an interposition graft.
        - Clamp times in excess of 30 minutes significantly increase the risk of paraplegia.
    - Left heart bypass is a form of active perfusion in which the inflow cannula is placed in the left atrium via the left atrial appendage or pulmonary vein and the outflow cannula is placed in the femoral artery.
        - Provides perfusion to distal organs and spinal cord while the aorta is cross clamped reducing the risk of paraplegia.
        - Less heparin is required since there is no oxygenator.
    - Utilization of full cardiopulmonary bypass is often via the cannulation of the femoral artery for perfusion and femoral vein to drain the right atrium and venous system. This provides improved distal perfusion and reduces the risk of paraplegia.
        - Heparin bonded bypass circuits help avoid systemic anticoagulation and reduces bleeding.
        - The oxygenator insures adequate oxygenation and the heat exchanger permits cooling of the patient which can both improve spinal cord protection and provide a circulatory arrest option should it become necessary.

Endovascular Repair

- Thoracic endovascular aortic repair (TEVAR) has become the primary modality used to repair BTAI. This procedure eliminates the need for thoracotomy and bypass and has been shown to have lower rates of morbidity and mortality.
- The left femoral artery is accessed via either a direct cut down or percutaneously, followed by sheath placement for the stent graft insertion and deployment. Systemic heparinization is determined by the patient's associated injuries, specifically the presence of a traumatic brain injury. The right femoral artery is accessed percutaneously with pigtail catheter placement for intra-operative angiography.
- Following TEVAR deployment, a completion angiogram is performed to demonstrate appropriate placement and insure that there is no endoleak or graft collapse that would require revision.
- Due to the short length of the stent and proximal location, and hence resultant small proximal nature of these injuries requiring limited aortic coverage, lumbar drains are not routinely placed for spinal cord protection.
- While the need to cover the left subclavian artery during a TEVAR repair may not be avoidable, a carotid to subclavian artery bypass is still not often required in the acute trauma setting. Cases that would require revascularization include patients with a patent LIMA to coronary artery bypass graft, limited posterior cerebral circulation, a dominant left vertebral artery, a left upper extremity arteriovenous fistula, or development of left upper extremity ischemia/claudication.

<u>**Post-Procedure Management**</u>

- Patients are placed on an ASA with a hemodynamic goal of maintaining a normal blood pressure. Some centers maintain a MAP goal between 80-90 following TEVAR placement for 48-72 hours to prevent spinal cord ischemia.
- Patients require serial imaging to confirm the integrity of the repair and to rule out the development of post-TEVAR complications.
- A post-operative CT angiogram is performed prior to discharge.
- Out-patient follow up with imaging is currently at 1, 6, and 12 months and then annually.
- Recent experience has demonstrated relative stability of endovascular grafts on follow up CT imaging. This has led some to suggest that if the patient's follow up imaging has remained stable over the first 1-3 years, less frequent long term follow up with surveillance CT scanning should be feasible and help reduce radiation exposure. MRI is also an option to help reduce the frequency of CT scanning and accumulation of radiation.

Complications

- Post TEVAR complications relating to the device include:
    - stent graft migration
    - structural failure or collapse
    - endoleaks
        - Endoleaks are complications that prevent the complete isolation of the aortic lesion being treated by the endograft and can be classified based on the underlying etiology
            - Type I endoleak is associated with a leak or failure at the proximal or distal attachment site of the endovascular graft and direct flow from the aorta into the excluded lesion exists. This requires intervention and treatment. Late presentation can be related to the proximal dilation of the native aorta.
            - Type II endoleak is associated with branch or collateral flow into the aortic lesion. Many can be observed and may spontaneously resolve although their natural history remains uncertain. When intervention is necessary arterial embolization is a common initial technique.
            - Type III endoleak is associated with a structural failure of the endograft that can be related to either fabric or graft disruption. Management is often with endovascular repair or revision.
            - Type IV endoleak is associated with porosity of the graft wall. These are often self-limiting and observed.
- Many such findings may necessitate TEVAR revision while type II endoleaks can often be initially observed.
- Peripheral vascular injury has also been reported and often requires repair of the femoral vessels and or a distal lower extremity embolectomy.
- Left upper extremity ischemia has been reported in a minority of cases following left subclavian artery coverage. Treatment is with a carotid to subclavian bypass.
- Paraplegia has more often been associated with open repair, yet it still has infrequently been reported following endovascular repair. It also appears to be declining at centers with a highly experienced open surgical team.
- CVA is another uncommon CNS complication following TEVAR yet it does appear to occur more frequently after endovascular rather than open repair.

Considerations for Special Populations

- Pediatric patients have small aortas that may not be compatible with FDA approved aortic stents.
- The natural history of young patients' aortas with endovascular stents is uncertain, with concern for the risk of developing aortic dilatation. Young patients are also anticipated to require long term follow up over decades which can put them at risk

for complications related to extensive radiation exposure. Follow up guidelines should be revised to decrease routine CT scanning in stable patients by reducing the frequency of imaging and increasing the utilization of MRI.

- Older patients with history of CABG often have an existing LIMA to LAD graft and a TEVAR that would cover the left subclavian artery would compromise the inflow to the LIMA putting the patient at risk for MI and catastrophic complications.

Suggested Readings

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