Approach to Extremity Vascular Injury

Mark W. Bowyer

Introduction:

Trauma to the extremities represents one of the most common injury patterns seen in emergency medical and surgical practice. Unfortunately, the extent of injury is often underestimated, incorrectly treated, and occasionally undiagnosed leading to preventable morbidity and mortality. All providers caring for victims of trauma must be aware of the likely extremity injuries based on mechanisms of injury, and proficient in their initial management to ensure optimal outcomes. Patients with extremity trauma often have other associated and potentially life-threatening injuries that must be identified and treated following accepted principles. Every standardized approach to the trauma patient, whatever the country of origin, teaches a systematic, stepwise approach to the trauma patient that minimizes the chance of a missed injury or of inappropriate management.

As extremity injuries are evaluated, each of the four functional components (nerves, vessels, bones, and soft tissues) must be considered individually and together. Initial treatment (after correction of other life-threatening injuries) is focused on stopping bleeding, stabilizing fractures, restoring or maintaining perfusion, and prevention or treatment of compartment syndromes. Best outcomes are achieved with a standardized multidisciplinary approach overseen by the general surgeon with specialist input from orthopedic, vascular, plastic, and rehabilitation specialists as needed. In resource-limited environments, some or all of these specialists may be unavailable, so it is crucial for the treating surgeon to understand all aspects of care. Our goal is to teach principles of initial and definitive management when timely referral to specialist care is impossible.

Etiology

Extremity injuries can result from a myriad of etiologies including falls, motor vehicle collisions, industrial and sports injuries, penetrating injuries and blast. The nature and severity of extremity injury differs between civilian and military settings.

Civilian extremity injuries most often occur due to falls (50-60%), industrial or work-related accidents, and motor vehicle crashes, though penetrating trauma is found in up to 12% of reported civilian series. In civilians with nonfatal trauma, extremity injuries are the most common reason for hospitalization, with 1/3 of those having serious or limb-threatening injuries.

In contrast, over 50% of the injuries recorded in the recent conflicts in Iraq and Afghanistan involve the extremities with up to 25% of those having associated serious non-extremity injuries. Military combat wounds are predominately penetrating in nature with 81% from explosions and 17% from gunshot wounds. Many of these injuries involve multiple functional components and are at high risk of both compartment syndrome and amputation.

Initial Evaluation and Management

The initial resuscitation, diagnostic evaluation, and management of any trauma patient regardless of mechanism is done in a standardized approach- we advocate using the principles taught in the Advanced Trauma Life Support (ATLS®) program established by the American College of Surgeons Committee on Trauma. Evaluation begins with a primary survey and assessment. Resuscitation and management of life-threatening injuries of the head, thorax, abdomen, and pelvis take precedence over extremity injuries. Following and in conjunction with airway (A) and breathing (B), evaluation and management in the primary survey, prompt attention should be turned to control of hemorrhage (C). External bleeding from the extremity, and especially bleeding from junctional areas (axillary or common femoral arteries) can be life threatening and should be controlled as soon as possible.

Bleeding from lower extremity vascular injuries can generally be controlled with direct pressure, though prolonged application of direct pressure is not always practical. A number of other approaches have been endorsed in the pre-hospital setting, including topical hemostatic agents, external compression clamps, and endovascular occlusion devices. “Blind” clamping of vessels (applying a clamp in poor visibility due to excessive bleeding) is not recommended. The use of tourniquets has recently emerged as a standard for pre-hospital and initial hospital control of bleeding. A prospective study of 232 combat casualties found a significantly

improved survival rate (77% vs 0%) when using a tourniquet (prehospital or emergency department) vs. no tourniquet, with no amputations required as a result of tourniquet usage. Similar results have been reported in civilian trauma patients for both pre-hospital and in-hospital tourniquet application. It is important to diagnose arterial bleeding early, so a detailed vascular assessment of injured extremities must be performed. It is important to recognize the "hard" signs of vascular injury, which are:

- Active hemorrhage
- Expanding or pulsatile hematoma
- Bruit or thrill over the wound
- Absent distal pulses
- Extremity ischemia

In penetrating trauma the presence of a hard sign of arterial injury is nearly 100% predictive of vascular injury warranting surgical repair. Such patients should be taken directly to the operating room for surgical exploration and on-table angiogram if indicated.

With blunt trauma, the hard signs are less reliable and false positives are common. It must be kept in mind that long bone fractures of humerus, femur, and/or tibia, even when not open, may provoke massive bleeding and hypovolemic shock as well as increasing the risk of compartment syndrome. Correct fracture immobilization can significantly reduce bleeding and provide pain relief. This should be performed during the resuscitation period. Usually reduction of fractures is done without the benefit of X-rays, in the acute phase of the evaluation. Repeat the physical examination after resuscitation, warming and reduction and splinting. Evaluate for any injuries with CT or conventional angiogram if there are persistent diminished pulses or other signs of vascular injury.

In a resource-limited setting, where angiogram is not available, decision-making can be difficult. Certainly blunt trauma patients with hard signs of vascular injury distal to an extremity laceration should be treated as penetrating trauma and taken to the operating room.

This patient was referred to a tertiary facility 36 hours after sustaining an open pelvic fracture and this right groin laceration in a motorcycle accident. The right leg was cold and pulseless; the laceration had been sewn shut. On exploration of the wound, the thrombosed external iliac artery (Black arrow) was seen. Because of the duration of time since the injury, revascularization was not considered and he underwent a hip disarticulation.

Patients with significant blood loss should be rapidly resuscitated with balanced blood products (packed cells, platelets, and fresh frozen plasma) or whole blood utilizing massive transfusion protocols if indicated. If bleeding is not yet controlled, the goal of such resuscitation should be "permissive hypotension" with a goal of a systolic pressure not less than 90.

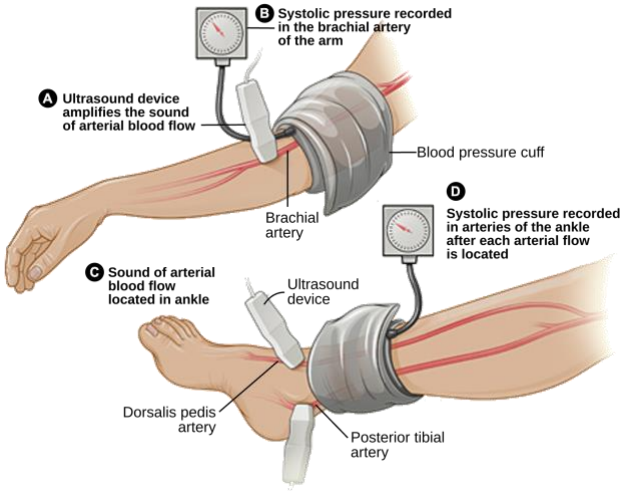
Patients with significant extremity trauma have a high likelihood of associated pelvic fracture, which can be a source of exsanguinating hemorrhage. A diligent search for pelvic fractures should be part of the primary survey, with management as described elsewhere in this Manual.

Secondary Assessment

Once the primary survey is complete and the life-threatening problems addressed, perform a secondary survey to include a full assessment of the musculoskeletal system as part of a head-to-toe evaluation. More information about the mechanism of injury as well as the past medical history should be obtained. The first step of the physical exam is to make sure the patient is completely exposed (avoiding hypothermia); any bandages or immobilization devices (except femoral traction splints) are removed and reapplied after examination.

During the secondary assessment, it is important to measure an injured extremity index (IEI) which is the ratio of the systolic pressure of the

injured extremity to an uninjured one. This measurement was previously known as "Ankle-Brachial Index" and involves measuring the systolic blood pressure of the injured limb, divided by the systolic pressure of a normal limb. Both values are measured with a manual blood pressure cuff and a doppler ultrasound.

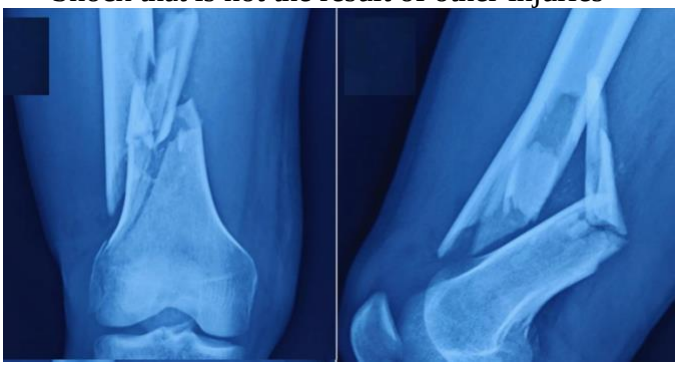


Injured extremity index (IEI) measurement. This has also been called the Arterial Pulse Index (API) and the Ankle Brachial Index (ABI) in the past. The blood pressure cuff should not be applied directly over a fracture. Source: By Jmarchn - Own work, CC BY-SA 3.0 https://commons.wikimedia.org/w/index.php?curid=31168075

A normal IEI (>.9) has a high negative predictive value for vascular injury and will allow for that patient to be observed or managed without immediate vascular imaging. In the absence of hard signs of vascular injury, an abnormal IEI (≤ .9) may indicate an occult vascular injury which warrants further investigation (ie CT angiogram) if persistent after warming and resuscitation of the patient.

It is also important during the secondary survey to look for "soft signs" of vascular injury which warrant further diagnostic evaluation or continued close observation. The soft signs include:

- A history of significant hemorrhage at the scene
- Proximity of penetrating wound, bony injury or blunt trauma to a major artery
- Decreased pulse compared to the contralateral extremity
- Peripheral nerve deficit
- Small non-pulsatile hematoma
- Abnormal Injured Extremity Index (<0.9)
- Abnormal flow-velocity waveform on Doppler ultrasound
- Shock that is not the result of other injuries



A distal femur fracture, adjacent to where the superficial femoral artery passes through the adductor muscles, should raise suspicion of a vascular injury. This is an example of proximity of a bony injury to a major vascular structure. Source: 10.7759/cureus.16613

A posterior knee dislocation is often caused by a low-speed impact below the knee, such as the bumper of a car. This injury is classically associated with a popliteal artery intimal tear, complete vascular occlusion, and a high risk of limb loss if not correctly managed. Source: Kael Duprey and Michelle Lin - CC BY 4.0 https://commons.wikimedia.org/w/index.php?curid=69378236

A systematic musculoskeletal exam of the extremities should include:

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1. **Inspection**: The patient should be examined from head to toe searching for any swelling, abrasions, injuries, hyperemia, or deformity suggesting a fracture or dislocation, comparing to the other limb when possible. Lacerations should be assessed for proximity to fracture sites and joint spaces. If joint injury is suspected CT is the preferred way to assess, but if not available or practical, injecting the joint with saline may assist with identifying these injuries. Lacerations in close proximity to fractures should be assumed to be open and treated as such.
2. **Active motion**: If the patient is able to cooperate, the patient is asked to flex and extend joints noting any asymmetry or inability to perform.
3. **Palpation**: A careful search is made for tender points, bony protrusions, and crepitus or crackles. The muscle compartments of the affected extremity should also be carefully inspected, maintaining a high index of suspicion for compartment syndromes.
4. **Passive motion**: The limbs are moved through their range of motion with any pain or abnormality noted and further investigated.

If the patient is unconscious, disoriented or under the influence of drugs or alcohol, injuries can be missed. It is even more important to perform a comprehensive examination of the extremities with visualization, palpation, and passive motion identifying and imaging any abnormalities. It is also important to perform a tertiary survey in the subsequent inpatient setting once the life and limb threatening injuries have been identified and treated.

Initial Radiographic Imaging

All patients with significant blunt trauma should have a chest and pelvis X-ray as an adjunct to the primary survey to rule out life threatening injuries in the thorax or serious pelvic fractures. Any obvious long bone fractures (especially with vascular compromise) should be reduced and immobilized prior to imaging. If there is suspicion of traumatic pathology in the head, neck, chest, abdomen or pelvis, the patient should undergo CT and or CTA (if this is available) of these regions prior to obtaining plain films of suspected extremity injuries. Radiographs should and can be taken with radio-transparent immobilization devices. The radiographs should include joints adjacent to the affected segment. In children and adolescents, it is important to image the contralateral limb as well- epiphyseal growth plates can sometimes be misdiagnosed as fractures.

In the right hands, Duplex ultrasound, which is highly operator dependent, can detect arterial disruption or occlusion, intimal flaps, venous occlusion, hematoma, pseudoaneurysm, or arteriovenous fistula. If CT is not available to you, try to build this capacity in your facility.

Principles of Immobilization

Immobilization of fractures is an important skill that should be mastered by all caring for victims of trauma. It starts in the prehospital setting. Proper immobilization will decrease pain, restore circulation, and limit additional injury from movement. Upon receiving a polytrauma patient with extremity fractures, the receiving provider should, in the secondary survey, remove and then replace all immobilization devices to perform a full exam and confirm adequate immobilization. It is also important to remove any items that may cause constriction of the injured extremity.

The basic principle of fracture management is to immobilize the joint above and below the injured bone. Specific injuries should be immobilized as follows:

- **Hand and wrist**: Immobilize in the anatomic position, with a volar splint for the wrist and/or fingers, discrete wrist dorsiflexion, and slight flexion of the fingers.
- **Forearm**: Immobilization should include the elbow at 90° flexion and the wrist in neutral position with a “sugar tong” splint.
- **Elbow**: Immobilize the elbow in a flexed position with a double “sugar tong” splint.
- **Arm and shoulder**: The shoulder and elbow are immobilized by bandaging close to the chest or using a “swath and sling.”
- **Clavicle**: A “Figure of 8 bandage” can be a definitive treatment for middle third fractures, the patient can be placed in an arm sling for transport.

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- **Femur**: A femur fracture can be immobilized with a traction device applied on the ankle or by bandaging one leg to another.
- **Tibia and Fibula**: Splinting with a rigid or pneumatic splint extending from above the knee to below the ankle.
- **Knee**: The knee should be splinted with slight traction or discrete flexion to include a pad under the knee to reduce discomfort.
- **Ankle**: Ankle injuries can be immobilized with padded splints with 90° of dorsiflexion (Posterior ankle or Stirrup splint), avoiding pressure on the bony prominences.

An improvised lower extremity splint in a low-resource setting made from a crutch, padding, and bandage material. This splint is described elsewhere in this Manual. Source: https://doi.org/10.1016/j.afjem.2021.02.007

Open Fractures

Open fractures occur when there is communication between the fracture and the external environment. As such any open wound in close proximity to a fracture should be considered an open fracture until proven otherwise. The presence of air in the soft tissue near a fracture on radiographic evaluation also suggests exposure of the injury to the environment and as such contaminated. Open fracture classification attributed to Gustilo and Anderson (Table) is a useful tool to help plan management.

Type	Wound Size	Contamination	Soft Tissue Injury	Bone injury
I	<1 cm	Clean	Minimal	Simple
II	>1cm	Moderate	Moderate	Moderate
IIIA	<10 cm	Extensive	Severe (Coverage Possible)	Comminuted fracture
IIIB	>10 cm	Extensive	Severe (Coverage Impossible)	Comminuted fracture
IIIC	>10 cm	Extensive	Associated vascular injury requiring repair	Comminuted fracture

Table: *Open fracture classification (Gustilo and Anderson)*

The management of open fractures should begin at the trauma scene with isolation from the contaminated external environment as soon as possible. Patients with open fractures should receive antibiotics, anti-tetanus immunization and prompt (within 6 hours of injury) washout, debridement, and stabilization of the fracture. The associated wounds should NOT be initially sutured regardless of the size and degree of contamination.

Fractures associated with Vascular Injuries- General Principles

The prognosis of fractures associated with vascular injury depends on the duration and degree of ischemia. Prompt diagnosis and direct treatment of vascular injury reduces further damage. Maintain a high index of suspicion for fracture-associated vascular injury. There are certain injuries that have a risk of associated vascular injury such as:

- Shoulder dislocation – axillary artery;
- Supracondylar humerus fracture – brachial artery;
- Femur fracture – superficial femoral artery;
- Posterior knee dislocation – popliteal artery.

The general surgeon (without vascular surgical expertise) tasked with caring for patients with fracture-associated vascular injury of the extremities should be well versed in obtaining proximal and distal control of major extremity vessels, performing damage control vascular shunting, and performing fasciotomies of the extremities.

If available, in patients who are not actively bleeding and in need of operative intervention, CT angiogram is the diagnostic modality of choice in patients with suspected vascular injury.

Operative strategy for vascular injury of the extremities

- Restoration of flow (via shunting or vascular reconstruction) that occurs within 3 hours of injury has the best outcome.
- The patient must be properly positioned (and prepared) on the operating table to expose all relevant vessels, allow for harvesting of veins, assessment of distal perfusion, and on-table angiogram.

- Proximal control should be obtained proximal to the injury where possible. Proximal and distal control may require separate incisions. Keep in mind that proximal control can be obtained with a tourniquet in selected extremity injuries.
- Selected use of balloon tamponade is useful for temporary control of hemorrhage from junctional or deep, difficult to access areas.
- Control of vessels is best achieved by vessel loops passed twice around the vessel (Potts Technique). If clamps are used, they should be atraumatic and applied with a minimum of force.
- In the setting of polytrauma with physiologic compromise or a surgeon not experienced in vascular repairs, the initial management should be damage control shunting. This procedure is addressed in another chapter of the Manual.
- Systemic anticoagulation should be avoided in patients with polytrauma.
- Fasciotomy should be liberally used in extremities with vascular injury. This procedure is described in another chapter of the Manual.

Disclaimer

The opinions or assertions expressed herein are those of the author and are not to be construed as official or reflecting the views of the Department of Defense, the Uniformed Services University of the Health Sciences, or any other agency of the U.S. Government. The author has nothing to disclose.

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