Penetrating nontorso trauma: the extremities

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Accepted for publication
Mar. 4, 2015

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DOI: 10.1503/cjs.005815

Summary

Similar to penetrating torso trauma, nontorso injuries have undergone a fascinating oscillation between invasive and noninvasive approaches. This article discusses an organized approach to the evaluation and initial treatment of penetrating extremity injuries based on regional anatomy and clinical examination. The approach is reliable, efficient and minimizes both delays in diagnosis and missed injuries. Outpatient follow-up is particularly important for patients with extremity injuries who are discharged home from the emergency department.

Similar to penetrating torso trauma,[1] nontorso injuries have undergone a fascinating oscillation between invasive and noninvasive approaches. The history of managing penetrating peripheral extremity vascular wounds includes some of the most notable surgeons within the history of surgery.[2] The aim of this discussion is to outline a logical and systematic approach to the diagnosis and initial management of penetrating extremity trauma.

Peripheral extremity trauma remains the most common source of vascular injury (51%), with the femoral artery continuing to be the most frequently injured vessel (35%).[3] More specifically, 6% of all patients with penetrating extremity trauma sustain a vascular injury compared with less than 1% of patients with blunt injuries.[3] Associated regional trauma is also common in the context of an extremity arterial injury and includes major veins (31%), nerves (27%) and bones (26%).[3] It is interesting to note that the treatment of extremity vascular injuries has evolved substantially over the past 100 years.[2] This improvement is best indicated by a progressive decrease in amputation rates owing to specific advances within military conflicts (World War I 16% [exsanguination], World War II 50% [prolonged tourniquet use and vessel ligation], Korean War 13% [primary vessel repair], Vietnam War 12% [rapid transport and primary vessel repair], Middle Eastern conflicts 3%–20% [early temporary intravascular shunts]).[3]

The ability to temporize ongoing hemorrhage via proximal occlusion (i.e., compression or tourniquet) offers a distinct advantage for the rapid management of extremity injuries over torso wounds of similar magnitude (i.e., "no vessel outside the human trunk is larger than the human thumb"). The work-up of penetrating extremity injuries also emphasizes physical examination as the mainstay of the diagnostic algorithm.[4] Although the specific operative management of these injuries is beyond the scope of this discussion, the ability of the clinician to obtain proximal vascular control with ease in addition to the absence of concern over gastrointestinal contamination makes the diagnosis and initial management of extremity trauma extremely rapid.

It should be re-emphasized that an immediate evaluation of the entire body (including the torso) is essential as a first manoeuvre upon the arrival of any patients with a penetrating injury (Fig. 1).[1] Ruling out additional life threatening overt or occult hemorrhage clearly precedes the salvage of limbs. A rapid primary survey of the extremities is then warranted. This should include evaluation for bony, nervous, vascular and soft-tissue injuries. Beyond initial palpation of the limbs, radiographs with wound markers (e.g., paper clips) are mandatory to rule out fractures. Similarly, if the patient is interactive, evaluating the neural integrity (motor and sensory) of the limbs is crucial. All active bleeding must be stopped by digital occlusion/direct pressure, balloon tamponade,[5] or proximal tourniquet before proceeding with any diagnostic or therapeutic endeavours. All long, bony fractures should be reduced before assessing for alterations in or a return of distal pulses.

Although the indications for immediate transfer to the operating theatre (Box 1) and/or "hard" signs that should trigger interventions (Box 2) are not debated, it is becoming increasingly evident that shortening the time interval to reperfusion of the extremity is essential. More specifically, reperfusion before the traditional 6-hour ischemia cutoff clearly results in improved long-term function of the extremity.[6] It must also be remembered that arteries with a complete transection tend to spasm and stop bleeding below systolic blood pressures of 80 mm Hg, whereas partial thickness arterial lacerations are not able to contract and therefore continue to hemorrhage (regardless of systemic hypotension).

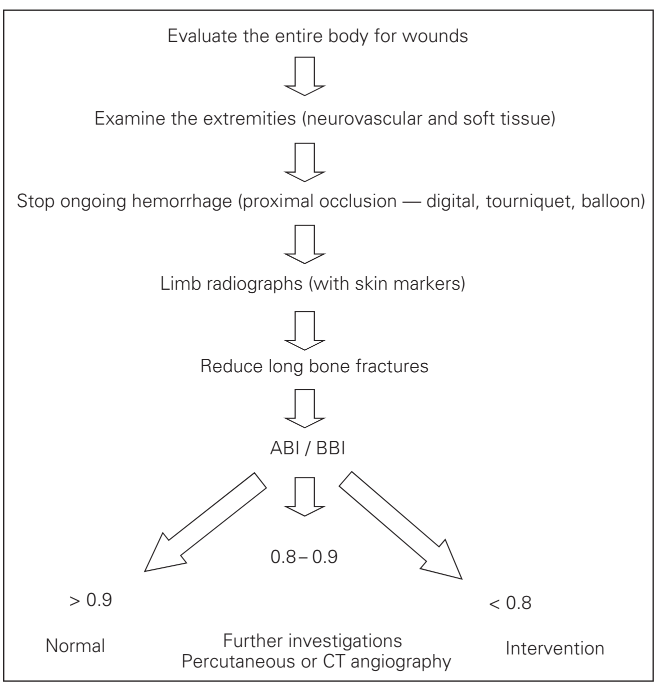

Fig. 1. Model for the evaluation of patients presenting with a penetrating injury. ABI = ankle-brachial index; BBI = brachial-brachial index; CT = computed tomography.

Box 1. Indications for immediate transfer to the operating theatre

1 Ongoing hemorrhage or rapidly expanding hematoma of the extremity despite proximal occlusion
2 Partial or complete amputation/mangling of the extremity
3 Non-extremity indications for emergent cavitary surgery

Box 2. Hard clinical exam signs that typically trigger interventions

1 Palpable thrill
2 Audible bruit
3 Pulselessness (and/or additional signs of occlusion: pallor, paresthesias, pain, paralysis, poikilothermia).

Evaluating the vascular status of a limb requires multiple steps. Although pulse status is important, it must also be remembered that distal pulses will continue to be present in many limbs with confirmed significant arterial injuries via propagation of the pulse through a column of blood clot. Similarly, although bruits secondary to acute ateriovenous fistulas (AVF) occur immediately following the injury itself, auscultation is very challenging within a noisy trauma bay environment. The subsequent step in the diagnosis of extremity vascular injuries is obtaining an ankle-brachial (ABI) and/or brachial-brachial index measurement.[3,4] This technique requires a sphygmomanometer and audible Doppler machine or stethoscope. The pressure at which the audible pulse is detected in the injured limb (numerator) is compared (ratio) to that within the noninjured limb (denominator). If this ratio is greater than 0.9, the incidence of a clinically relevant vascular extremity injury is negligible. If the ratio is less than 0.8, the chances of the patient possessing a true vascular injury is very high (sensitivity 95%).[7] In this scenario, many surgeons proceed directly to the operating theatre on an urgent basis. If the ratio is between 0.9 and 0.8, however, further investigations (angiography) are typically warranted. It should be noted that these ratios can be affected by severe limb hypothermia, so ensuring a warm trauma bay environment is crucial. Additional "soft" signs of extremity vascular injury that may necessitate further diagnostic evaluation include a neurologic deficit adjacent to a named vessel, bony dislocation/fracture adjacent to a named vessel and small nonpulsatile hematomas. Any of these soft signs in isolation will yield a vascular injury rate of approximately 10%.[3] Variant combinations will yield injury rates between 3% and 25%.[8] It should be noted that despite the very high sensitivity inherent within ABIs, clinically less significant nonocclusive vascular injuries remain possible with an ABI > 0.9 (i.e., intimal flap, spasm, subintimal or intramural hematoma, tiny pseudoaneurysm).[9] These are rarely treated with intervention.

There have been several trends regarding the role of angiography in extremity trauma over the past decades. More specifically, routine bedside emergency department (ED) angiography by the trauma service for all extremity wounds (i.e., using indications such as wound proximity) has long since been shown to be unnecessary.[10] Although the specific angiographic modality of choice is debatable, patients with an ABI less than 0.9 require a definitive diagnostic arteriogram. Options include ED angiography using either multiple "single-shot" radiographs (30 mL injectable contrast), C-arm fluoroscopy, or Lodox continuous gantry technology.[11] In most developed centres, however, more formal angiography with either computed tomography (CTA) or percutaneous techniques is preferred. Given recent improvements in the fidelity of CT (i.e., 3-dimensional reconstruction), CTA is the first choice of many clinicians.[12] If, however, the surgeon's pretest probability of a vascular injury is high (concerning clinical exam and ABI < 0.9), angiography at the time of operative exploration may be more expedient. Although patency of most lower-extremity vascular repairs should be confirmed with an angiogram before leaving the operating suite, the return of distal pulses, capillary refill and warmth to the injured upper limb is usually sufficient to avoid a formal study. It should also be noted that in patients who sustain shotgun or blast/shrapnel injuries, angiography should be performed immediately after hemorrhage control but before reconstruction to rule out the common occurrence of multiple sites of vascular injury. Similarly, temporary intravascular shunts should be placed liberally[13] and clearly before the limb fracture is reduced and fixated (e.g., in a Gustilo IIIC injury).[14] Decisions about limb salvage should not be made within the trauma bay. These patients require a detailed operative examination under optimal conditions with the input of experienced colleagues (orthopedic, vascular, plastic surgery teams). In the work-up of a potential lower-extremity vascular injury, it must be remembered that a limb is rarely compromised in the context of an arteriogram showing patency of at least 1 of the 3 major arteries below the knee. Given that the peroneal artery has no anatomically palpable pulse, it is not surprising that 50% of missed vascular injuries occur below the knee joint. In addition, posterior dislocations of the knee in the context of diminished or absent pedal pulses (after reduction) mandate immediate arteriography.[15]

Evaluation for extremity compartment syndrome must be considered early in the work-up or intervention for cases of prolonged ischemia, long prehospital intervals, crush injury, and/or tourniquet usage. Compartment pressures are easily measured with a long catheter, tubing and pressure transducer. The deep compartment is at particular risk owing to location and dual arterial residency. Pressures greater than 30 mm Hg generally compromise capillary flow and warrant immediate decompression (2-incision [4 compartment] approach for lower extremity and 1-incision [3 compartment] approach for upper extremity). It must also be considered that even in the extremity with frank compartment syndrome, the arterial systemic pressure is higher than the limb compartment pressure, therefore ensuring a continuing and dangerously misleading pulse on examination.

If the patient does not appear to have a bony, neurologic, or arterial injury of concern, a venous laceration remains possible. In cases where ongoing dark hemorrhage is not draining from the leg, the patient must be mobilized before discharge. More specifically, they must pressurize their lower extremity venous system by walking a reasonable distance within the ED. If this does not induce new hemorrhage, the patient can be safely discharged. Although there remains no practical role for venograms, prehospital reports of massive bleeding at the scene with no appreciable hemorrhage in the trauma bay are often consistent with venous injury. Patients must be followed in an outpatient setting within 1–2 weeks. During this visit, a physical examination to rule out the development/progression of AVF or arterial pseudoaneurysms is essential.

Percutaneous techniques are rapidly evolving in the treatment of extremity penetrating wounds with either proximally controlled hemorrhage or minimal ongoing bleeding. Therapeutic embolization is a reasonable approach for isolated traumatic aneurysms of branches of the subclavian, axillary, brachial, common femoral, superficial femoral, popliteal and shank arteries as well as pseudoaneuysms/AVFs of the distal profunda femoris. Similarly, endovascular stents/grafts are possible for subclavian artery pseudoaneurysms without ongoing hemorrhage into the pleural space. Finally, although there are multiple limb injury scoring systems available to the clinician, they cannot reliably predict the need for amputation among the majority of patients.

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Competing interests: None declared.

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