Vascular injury in orthopedic trauma is a potentially limb- and life-threatening event that represents a challenge for every orthopedic surgeon and clinician involved in the primary care of trauma patients. Whether encountered in the emergency department or in the elective setting, loss of limb or life can easily occur if the diagnosis of an associated vascular injury is missed or delayed. Under these circumstances, a rapid and accurate diagnosis, as well as a thorough understanding of the management priorities implicated is of paramount importance for successful salvage of the limb.

At the beginning of the 20th century, Alexis Carrel (1873-1944) and Charles C. Guthrie (1880-1963) at the University of Chicago were among the first to develop standard vascular operative techniques, including repair of the lateral arterial wall, end-to-end anastomosis, and insertion of venous interposition grafts. Since then, the management of vascular trauma has evolved mainly through the contribution of armed conflicts, including repair of the lateral arterial wall, end-to-end anastomosis, and insertion of venous interposition grafts. Since then, the management of vascular trauma has evolved mainly through the contribution of armed conflicts, Ligations and ampu...
tations remained the rule until the end of World War II (1939-1945).\textsuperscript{5,9} A major shift in this attitude occurred during the Korean War, with 88% of injuries undergoing an attempt at primary repair or anastomosis (60%) or interposition grafting (27%).\textsuperscript{10-12}

In the Vietnam War (1954-1975), the development of forward surgical teams (FSTs) and advances in rotary wing casualty evacuation (CASEVAC) made primary arterial reconstruction even more feasible.\textsuperscript{13-16} The conflicts in Iraq and Afghanistan (Global War on Terror) brought significant advances in the management of vascular injuries in trauma,\textsuperscript{17} including redefinition of the concept of damage-control resuscitation,\textsuperscript{18,19} widespread early use of battlefield tourniquets,\textsuperscript{20,21} routine use of personal protective gear (body armor),\textsuperscript{22} frequent application of temporary vascular shunts, refinement of the organization of in-theater levels (echelons) of care,\textsuperscript{23,24} development of the Joint Theater Trauma System,\textsuperscript{25} the implementation of Clinical Practice Guidelines,\textsuperscript{26} and the institution of a Joint Theater Trauma Registry\textsuperscript{27} for collection and analysis of data.\textsuperscript{28} In the past decade, the establishment of the National Trauma Data Bank by the American College of Surgeons has allowed detailed descriptive data and adequately powered statistical analysis of a wide variety of vascular injuries and related trauma.\textsuperscript{28-31}

**Epidemiology**

The overall incidence of vascular injury following extremity trauma varies widely by population (military vs civilian), geographic location (urban vs rural), and mechanism of injury (penetrating vs blunt trauma).\textsuperscript{32,33} In a recent National Trauma Data Bank analysis, the incidence for vascular injury in orthopedic trauma was 1.6% for adults and 0.6% for pediatric patients,\textsuperscript{34} which is significantly lower than the 6% to 12% incidence among combat casualties.\textsuperscript{35} Patients with extremity vascular injuries tend to be younger (average age, 30 years) and predominantly (70%-90%) male.\textsuperscript{36,37} Even though this trend tends to change to elderly patients.\textsuperscript{38} In the austere environment, high-caliber rounds and explosive ordnance with shrapnel are the predominant wounding agents.\textsuperscript{35,39} The force, trajectory, and tissue damage associated with military injuries are much more devastating than those seen in civilian series.

Because nearly all vascular injuries in wartime are caused by blast or high-velocity weaponry, approximately 33% of those with vascular injuries have associated orthopedic injuries, and up to 20% have partial- or full-thickness burns and associated head or torso injuries.\textsuperscript{40} Lower-extremity vascular injuries occur at approximately double the rate of upper-extremity injuries in the military setting, reflecting the relative length of axial vessels and the exposed position of the lower extremity away from the protection of the torso.\textsuperscript{41} The superficial femoral artery is the vessel most commonly injured (33% to 37%), followed by the popliteal and tibial arteries (25% each).\textsuperscript{40,42}

In urban trauma centers in the United States, peripheral vascular injuries are mostly caused by low-velocity missile wounds from handguns.\textsuperscript{43} In contrast, stab wounds account for most of the civilian extremity vascular injuries in countries where firearms are more difficult to obtain.\textsuperscript{44} Vascular injuries from blunt orthopedic trauma, such as fractures, dislocations, contusions, crush injuries, and traction, account for only 5% to 25% of injuries that require treatment.\textsuperscript{45,46} The femoral or popliteal arteries are most commonly injured (50% to 60%), followed by the brachial artery (30%).\textsuperscript{43} Whether by blunt or penetrating mechanism, civilian vascular injuries frequently occur in association with high-risk behavior such as substance abuse, violence, and late-night hours.\textsuperscript{47} Rural settings have a higher proportion of blunt injuries, but they still comprise less than 45% of the total rate.\textsuperscript{37}

Vascular injuries associated with long bone fractures in otherwise healthy young trauma patients are relatively rare. The reported incidence of injuries to the superficial femoral artery in association with a fracture of the femur has been less than 1% to 2%.\textsuperscript{48} Injuries to the popliteal artery, tibioperoneal trunk, or trifurcation vessels occur in only 1.5% to 2.8% of all tibial fractures. When open fractures of the tibia are reviewed separately, the incidence of injury to the popliteal artery requiring surgical repair ranges from 16% to 20%.\textsuperscript{50}

The anatomy of the lower extremity predisposes the femoral and popliteal vessels to injury at certain locations during trauma. The popliteal artery runs through the popliteal fossa and is tethered proximally by the adductor hiatus and distally by the soleus arch. Therefore, high rates of vascular injuries are observed with specific lower-extremity injuries such as high-energy tibial plateau fractures (especially Schatzker types IV and VI fractures), high-energy displaced distal femoral fractures at the level of the adductor hiatus, open fractures of the femur, segmental femoral fractures, floating knee injuries, and posterior knee dislocations (Table 1).\textsuperscript{51} When observing any of these injury patterns, it is necessary to rapidly begin an evaluation for vascular compromise.\textsuperscript{51} The association between certain elective and emergency orthopedic operative procedures and arterial injuries also has been well documented.

**Types of Vascular Injury**

From a pathology standpoint, there are 5 types of vascular injury: (1) intimal injury (flaps, disruptions, or subintimal and intramural hematomas), (2) complete wall defects with pseudoneurysms or hemorrhage, (3) complete transections with hemorrhage or occlusion, (4) arteriovenous fistulas, and (5) spasm.\textsuperscript{52} Intimal defects and subintimal hematomas with possible secondary occlusion are associated most commonly with blunt trauma, whereas wall defects, complete transections, and arteriovenous fistulas
usually occur with penetrating trauma. Spasm can occur after either blunt or penetrating trauma to an extremity and is more common in young patients. When there is an injury to the intima or intima/media and dilatation of an artery occurs, this is a traumatic true aneurysm with no extravasation of blood outside the lumen of the artery. A full-thickness defect in the wall of an artery with extravasation of blood outside the lumen is an acute pulsatile hematoma immediately after injury and a traumatic false aneurysm when the surrounding tissues encapsulate the blood.8

**DIAGNOSIS**

Clinical presentation of vascular injury may not be straightforward. Physical examination can be misleading or initially unimpressive33; a normal pulse examination may be present in 5% to 15% of patients with vascular injury.53 Detection and treatment of vascular injuries should take place within the context of the overall resuscitation of the patient according to the established principles of the Advanced Trauma Life Support (ATLS) protocols.54 Bleeding from an injured extremity affects the “circulation” during the primary survey of ATLS and should be managed with direct pressure, a compressive dressing, or if that is not effective, with tourniquet application and ongoing resuscitation. In the absence of bleeding, the injured extremity is assessed during the secondary survey of ATLS. The secondary survey should include clinical examination of the extremities, followed by radiographic evaluation of the injured ones. Thorough neurologic and vascular examinations should be performed on arrival prior to any intervention (eg, reduction), and they should be repeated following the patient’s resuscitation.54

Vascular examination should include assessment of capillary refill and extremity color and temperature, as well as standard documentation of palpable, Doppler-evident, or absent pulses in the affected extremity. Results should be compared with the contralateral side. For the patient in whom physical examination findings change after any manipulation or intervention, further workup is required to rule out the presence of an iatrogenic vascular injury. Conversely, reduction of a fracture or dislocation may improve vascular status. Should first palpation of distal pulses document a difference between the injured and a contralateral uninjured extremity in a hemodynamically stable patient, a fracture or dislocation of a joint in the injured extremity should be realigned or reduced, respectively.46

Physical examination findings are classified into hard or overt signs and soft signs of vascular injury (Table 2). Hard signs of extremity vascular injury include massive bleeding, a rapidly expanding hematoma, any of the classic signs of arterial occlusion (ie, pulselessness, pallor, paresthesia, pain, paralysis, and poikilothermia), a palpable thrill, or an audible bruit.55-57 The incidence of vascular injuries in patients with any hard sign is consistently greater than 90%.58 When hard signs of injury are present, there is limited need for imaging diagnostic tests, such as computed tomography (CT) or conventional angiography, which take extra time and may provide findings that cloud decision making.24,25,40

In contrast, in these cases, immediate operation on the injured extremity is necessary,13 generally with exploration of the injury site with wide exposure to enable vascular exploration and repair. In the patient with other acute life-threatening injuries, such as an intracranial hematoma with midline shift, bleeding to the chest, abdomen, or pelvis, gastrointestinal contamination in the abdomen, and simulta-

<table>
<thead>
<tr>
<th>Skeletal Injury</th>
<th>Vessels at Risk</th>
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<tbody>
<tr>
<td>Clavicle or first rib</td>
<td>Subclavian vessels, brachial plexus</td>
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<tr>
<td>Humerus neck</td>
<td>Axillary artery and nerve</td>
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<tr>
<td>Humeral diaphysis and supracondylar area</td>
<td>Brachial artery, radial nerve</td>
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<tr>
<td>Acetabulum</td>
<td>External iliac; superior gluteal and femoral vessels; sciatic nerve</td>
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<tr>
<td>Femoral shaft</td>
<td>Superficial femoral artery</td>
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<tr>
<td>Supracondylar femur</td>
<td>Popliteal vessels</td>
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<tr>
<td>Proximal tibia</td>
<td>Popliteal artery, tibioperoneal trunk, tibial artery, peroneal artery; peroneal nerve</td>
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<tr>
<td>Distal tibia</td>
<td>Tibial or peroneal artery</td>
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<tr>
<td>Cervical spine</td>
<td>Vertebral artery</td>
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<tr>
<td>Thoracic spine</td>
<td>Descending aorta</td>
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<td>Lumbar spine</td>
<td>Abdominal aorta</td>
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<tr>
<td>Dislocations</td>
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<td>Shoulder dislocation (anterior)</td>
<td>Axillary artery and nerve</td>
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<tr>
<td>Elbow dislocation</td>
<td>Brachial artery; radial, ulnar, and median nerves</td>
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<tr>
<td>Hip dislocation</td>
<td>Femoral artery; sciatic nerve</td>
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<tr>
<td>Knee dislocation</td>
<td>Popliteal artery; peroneal and tibial nerves</td>
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<tr>
<td>Ankle dislocation</td>
<td>Posterior tibial artery; posterior tibial nerve</td>
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Table 2

<table>
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<tr>
<th>Hard and Soft Signs of Vascular Injury in Orthopedic Trauma</th>
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<tbody>
<tr>
<td>Hard sign</td>
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<tr>
<td>Pulselessness</td>
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<tr>
<td>Pallor</td>
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<tr>
<td>Paresthesia</td>
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<tr>
<td>Pain</td>
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<tr>
<td>Paralysis</td>
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<tr>
<td>Rapidly expanding hematoma</td>
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<tr>
<td>Massive bleeding</td>
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<tr>
<td>Palpable thrill or audible bruit</td>
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<tr>
<td>Soft sign</td>
</tr>
<tr>
<td>History of bleeding in transit</td>
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<tr>
<td>Proximity-related injury</td>
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<tr>
<td>Neurologic findings from nerve adjacent to a named artery</td>
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<tr>
<td>Hematoma over a named artery</td>
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</table>

From 3% to 25%, depending on which soft sign or combination of soft signs is present. The presence of peripheral pulses equal to those in the contralateral uninjured extremity is good evidence of no or limited arterial injury, such as intimal injury.

In this setting, in addition to a comprehensive physical examination, an arterial pressure index (API) or injured extremity index (IEI) should be performed. The API or IEI is similar to the ankle-brachial index (ABI) and is calculated using a manual blood pressure cuff and a continuous wave Doppler. The first step is to determine the pressure at which the arterial Doppler signal occludes in the injured extremity, which is the numerator in the equation. Next, the cuff and Doppler are moved to the uninjured extremity, and the pressure at which the arterial Doppler signal occludes is recorded, which is the denominator in the equation. An IEI greater than 0.90 is considered normal and has a high specificity for excluding a vascular injury. A patient with diminished peripheral pulses or an API less than 0.9 should undergo an imaging study, typically an arteriography, DUS, or CT angiography (CTA) to document the presence and location of a possible vascular injury.

Beyond the obvious hard or soft signs of vascular injury, physical examination of the injured extremity should include observation of the position in which the extremity is held, presence of an obvious deformity of a long bone or joint, presence or absence of an open wound or bony crepitus, skin color of the distal extremity compared with that of the opposite side (in light-skinned individuals), time required for skin capillary refill in the distal digits, and a complete motor and sensory examination. In the lower extremity, the stability of the knee joint should be assessed carefully; increased laxity may suggest spontaneous reduction of a knee dislocation. Because of the well-known association of knee dislocation (especially posterior) with popliteal artery injury, there should be a low threshold for obtaining imaging in such an instance. However, not all surgeons agree with this approach, advocating that routine imaging is not necessary after spontaneous or orthopedic reduction of a dislocated knee in the presence of normal pulses.

**IMAGING**

Local expertise usually dictates the imaging study to be selected to demonstrate the presence of a suspected vascular injury in the setting of orthopedic trauma. Angiography, CTA, and DUS are the modalities used for this purpose in most trauma centers.

Conventional catheter-based angiography was developed in the 1970s, allowing for accurate diagnosis of arterial injury with a less invasive procedure than open surgical exploration of the area of the presumed vascular injury. Conventional angiography options include conventional film, digital subtraction after intra-arterial or intravenous injection of a contrast agent, or surgeon-performed “1- or 2-shot” studies, either in the emergency department or the operating room. Three major disadvantages of arteriography are the cost of the procedure, the delay, and the need for a specialized team comprising a physician, angiography technologist, and nurse. Surgeon-performed percutaneous intravascular injection studies in injured patients have been associated with a complication rate of 1% to 4% and a sensitivity/specificity greater than 95%. As renal toxicity is a potential issue, adequate fluid resuscitation is mandatory. Currently, conventional angiography usually is reserved for intraoperative use.

Duplex ultrasound is a combination of real-time B-mode ultrasound imaging and pulsed Doppler flow detection. Numerous studies have shown a good accuracy of DUS in assessing vascular injury. Sensitivity ranges from 50% to 100%, whereas specificity and accuracy exceed 95%. Although inexpensive and noninvasive, DUS can be time-consuming and signifi-
surgical treatment. A single major vessel occlusion distal to the knee or elbow in the absence of severe soft tissue damage or a mangled extremity rarely constitutes a viability risk for the injured extremity. In such cases, observation might be a viable option. Serial imaging surveillance, however, is necessary. Nonocclusive arterial injuries such as spasm, intimal flaps, or intramural hematomas detected in angiography performed for soft signs of vascular injuries seem to heal without surgery in 87% to 95% of cases. Furthermore, isolated traumatic aneurysms in selected vessels may be treated by therapeutic embolization instead of an open vascular operation. In addition, certain vascular injuries such as intimal dissections and flaps or small pseudoaneurysms have been shown to be amenable to endovascular treatments with stents or stent grafts.

**Open Vascular Repair**

In the operating room, an operative tourniquet can replace the bleeding-control modality used previously. However, if the injury is too proximal or exsanguinating hemorrhage resumes, a member of the surgical team should be gloved and gowned in a sterile fashion, apply proximal pressure control, and the patient should be prepped and draped with this team member included in the surgical field.

For all locations of peripheral vascular injury, preparation of the skin and draping should encompass all potential areas of proximal and distal vascular control, the area where a distal fasciotomy would be performed, and one (or the ipsilateral) proximal and distal to the injury to ensure adequate exposure for proximal and distal vascular control and repair. Incisions typically are made longitudinally, directly over the target vessel proximal and distal to the injury to ensure adequate exposure for proximal and distal vascular control and repair. Incisions should provide comfortable exposure. After vascular control is achieved, the incisions can be extended as needed to expose the zone of vascular injury. When the area

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**Figure 1:** Sagittal computed tomography scan with 3-dimensional reconstruction showing contusion of the left popliteal artery in a 50-year-old woman with an open supracondylar femoral fracture. The pulse returned after reduction of the fracture.
of injury is in proximity to a joint, a gently curved (lazy “S”) incision to prevent a postoperative scar contracture is recommended. Not dissecting far enough proximally and distally from an area of injury is a common error. However, if control of hemorrhage cannot be obtained or an extensive hematoma is overlying the arterial injury, making it difficult to obtain control close enough to avoid backbleeding from collaterals, it is not inappropriate to enter the zone of injury directly.

After vascular control is obtained in either classic or direct fashion, vascular occlusion can be maintained by applying a small DeBakey clamp, bulldog clamp, or Silastic (Dow Corning Corporation, Auburn, Michigan) vessel loops.

In general, small lacerations can be addressed by lateral angiorrhaphy with 5-0 or 6-0 polypropylene sutures applied transversely (Figure 2). If this leads to significant narrowing, vein patch angioplasty is a viable alternative. In cases of complete transection of the injured artery, debridement back to healthy intima at both ends is performed, and the feasibility of an end-to-end anastomosis without tension is assessed (Figure 3); this normally is performed using 6-0 or 7-0 polypropylene sutures applied in a continuous or interrupted technique with 2 stay sutures 180° apart.

If the anastomosis is sewn under tension, an hourglass appearance will result at the suture line, which often leads to thrombosis in the postoperative period; in this case, the surgeon should opt for Fogarty embolectomy and either a redo anastomosis or an interposition graft. If an end-to-end anastomosis cannot be performed with minimal tension, a substitute conduit should be inserted. An autogenous reversed saphenous vein graft from an uninjured lower extremity remains the conduit of choice for most peripheral vascular injuries (Figure 4). Alternatives to the saphenous vein are use of either the cephalic or basilic vein, or insertion of a polytetrafluoroethylene graft. However, patency with these grafts seems to be significantly less in the long-term.

A vascular repair should never be left exposed. A significant soft tissue defect overlying a conduit or anastomosis will result in contamination, leading to infection. A decision must be made in conjunction with the plastic surgery service on whether there is healthy muscle close enough to be transposed or rotated to cover the vascular repair. Finally, a completion arteriogram should be performed to confirm

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**Figure 2:** Preoperative photograph showing an intima tear of the right posterior tibial artery in a 52-year-old man with a gunshot open tibial fracture (A). Intraoperative photograph showing surgical repair and fasciotomies performed through the posterior approach to the leg (B).

**Figure 3:** Preoperative photograph (A) and anteroposterior radiograph (B) of the ankle joint showing an open fracture-dislocation of the midtarsal (Chopart) joint of the right foot in a 35-year-old man. Surgical exploration after reduction and stabilization of the fracture-dislocation with external fixation showed transection of the posterior tibial artery that was repaired with end-to-end anastomosis. Photograph showing the foot 10 days after closure with a split-thickness skin graft (C).

**Figure 4:** Intraoperative photograph showing transection of the right brachial artery in a 6-year-old boy with a humeral diaphysis fracture; the arrows indicate the proximal and distal parts of the artery (A). Intraoperative photograph showing successful reconstruction of the brachial artery with a reversed saphenous vein bypass graft (arrows) (B).
patency, and identify and address technical issues.88,93,94

Compartment Syndrome

The development of compartment syndrome portends a poor limb outcome.95,96 The classically described diagnostic signs of the 5 Ps (pain, pallor, paresthesia, passive extension, and pulses intact) represent late signs of compartment syndrome and are frequently absent or obscured in trauma patients because of distracting injuries and altered mental status. The key clinical findings are pain out of proportion to the associated injury and pain on passive movement of the muscles of the involved compartments.95 The incidence of clinically relevant compartment syndrome after extremity vascular injury is unknown because of the widespread use of prophylactic fasciotomy in the setting of orthopedic or vascular surgery.96 Performance of a fasciotomy concomitant with or soon after revascularization of the limb is associated with a fourfold reduction in eventual amputation and other complications.97

Performance of a fasciotomy is most strongly predicted by the presence of a fracture or dislocation, a vein or nerve injury, or multiple arterial injuries.97 Early calf or forearm fasciotomy should be considered in all patients with restoration of digital perfusion after ischemia resulting from trauma, especially if multiple fractures or arterial injuries are present. Although fasciotomies complicate wound management and may require additional operative procedures for wound closure (Figure 5), their benefits, even when performed prophylactically, outweigh these risks.

Sequence of Repair

The ideal sequence of surgical repair in combined orthopedic and vascular injuries remains an area of debate.98 Proponents of performing the orthopedic intervention before the vascular repair argue that skeletal stabilization is required to protect the vascular repair and that manipulation, reduction, and internal fixation may endanger the repair.99 Decreasing warm ischemia time remains the primary argument in support of performing vascular repair first.31 It is difficult to argue against the statement that reversal of limb ischemia should take precedence. Even more confusing is the fact that a recent meta-analysis failed to demonstrate any statistically significant difference in overall amputation rate when vascular repair or orthopedic repair was performed first (13% vs 11.6%, respectively).98 Temporary versus definitive fracture fixation at the index procedure also is controversial, although most studies tend to favor temporary external fixation as a more reasonable, expedited solution.100,101

In general, it is recommended that the orthopedic procedure is performed first in (1) patients with neither cold ischemia (ie, pulseless limb or absent capillary refill) nor a prolonged period of warm ischemia (ie, present capillary refill), and (2) the setting of a very comminuted and unstable fracture pattern to facilitate subsequent vascular repair. In contrast, a vascular procedure should be performed first in (1) patients with a cold, pulseless limb and little or no capillary refill, and (2) patients who have undergone a prolonged period of either cold or warm ischemia. In these patients, restoration of arterial inflow has the highest priority and should be accomplished first by formal repair or by the insertion of a temporary intraluminal vascular shunt (TVS).60

A temporary intraluminal vascular shunt is an intraluminal plastic conduit for the temporary maintenance of arterial inflow/venous outflow.102 First described by Eger et al in Israel in 1971, the use of vascular shunts significantly increased in trauma centers for revascularization after trauma.39,104 The primary indications include need for damage control surgery, Gustilo-Anderson type IIIC open fractures, and preservation of an amputated upper extremity at the arm, forearm, or wrist level before replantation. In general, the initial use of a TVS to restore flow in the ischemic limb, followed by external fixation to stabilize the fracture removes the sense of urgency from the situation, allowing for the procedure to be quickly terminated and for the patient in extremis to be hemodynamically stabilized to return to the operating room for a formal, definitive vascular repair.105
A mangled extremity results from high-energy or crushing trauma that causes combined injuries to arteries, bone, soft tissue, tendons, and nerves that significantly compromise the viability of the limb. The management is challenging; the dilemma is whether to attempt limb salvage or opt for a primary amputation (Figure 6). The Mangled Extremity Severity Score (MESS) has been devised as a treatment decision aid; a score of 7 or more points usually indicates the need for primary amputation.107 Other indications for immediate amputation include: (1) a warm ischemia time of more than 6 hours in the presence of a crush injury that disrupts collaterals, (2) injury of the posterior tibial nerve, (3) associated severe polytrauma, (4) severe ipsilateral foot trauma, (5) anticipated protracted course for soft tissue coverage, and (6) anticipated need for multiple reconstruction procedures.108-110 In general, an attempt at initial limb salvage and early revascularization is recommended, especially when the decision of limb salvage versus primary amputation does not seem clear.109 One should keep in mind that a patient’s life should not be endangered by an injured limb (Figure 7).

CONCLUSION

Vascular injury in orthopedic trauma is challenging to manage. The risk to life and limb can be high. Clinical signs can be subtle initially. In the absence of clear signs of vascular compromise, these injuries can easily be missed, with potentially devastating consequences. Therefore, prompt recognition and management of vascular injury in orthopedic trauma is of paramount importance and should be undertaken in an orchestrated fashion with the overall care of the patient. Tertiary trauma centers ideally should have a clear protocol of activation of the appropriate trauma team including vascular, orthopedic, and plastic surgeons; colleagues should establish priorities, discuss the appropriate sequencing, communicate management decisions with the operating room personnel and anesthesiologists, and perform the repairs.

Although a cold limb requires urgent surgical exploration, resuscitation and management of associated life-threatening injuries should take priority over any extremity problems. Damage-control resuscitation with early blood transfusion is necessary in patients with hemorrhagic shock. Neurovascular status should be assessed in every injured extremity as a priority; findings should be documented clearly in the medical records as a timed entry. Active bleeding should be controlled in an expedited manner, either by tourniquet or a gloved hand compressing the bleeding site. The time of tourniquet placement should be carefully recorded.
Blind clamping or local wound exploration in the trauma bay should be discouraged as potentially detrimental. A deformed, pulseless extremity should be realigned and a dislocation reduced; neurovascular status then should be reassessed as reestablishment of flow is not infrequent. Imaging should include DUS, CTA, or on-table angiography; however, imaging should not delay reperfusion as the injury pattern usually predicts the level of vascular injury in most cases. Reperfusion delay with prolonged warm ischemia (>3-6 hours) leads to irreversible tissue damage, with resulting myoglobinuria and acute renal failure that may be life-threatening.

Limb salvage is not always the correct decision; in many cases, primary amputation may be the most reasonable choice. In any case, the patient and relatives should be made aware of the possible risks of surgery, potential for multiple procedures, and possibility of immediate or secondary amputation. Preparation for surgery should include (1) administration of broad-spectrum antibiotics, (2) tetanus toxoid, and (3) a bolus of systemic heparin as well as ensuring the injury is isolated and bleeding is under control.

The key factors in successful management are optimal sequence of the repair, adequate exposure and vascular control, debridement of the injured vessel wall to healthy intima, proximal and distal balloon catheter thrombectomy, tension-free end-to-end repair or appropriately sized interposition graft, good soft tissue coverage, stable but expeditious fracture fixation, and adequate fasciotomies. Failure to perform fasciotomies after revascularization of an acutely ischemic limb is the most common cause of preventable limb loss. Incisions for fasciotomies or vascular control should preserve perforating vessels, taking into account the future potential need for fashioning flaps for soft tissue coverage. Finally, a bed in the intensive care unit ideally should be reserved for early postoperative monitoring.

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