Western Trauma Association Critical Decisions in Trauma: Management of the mangled extremity

Thomas M. Scalea, MD, Joseph DuBose, MD, Ernest E. Moore, MD, Michael West, MD, Frederick A. Moore, MD, Robert McIntyre, MD, Christine Cocanour, MD, James Davis, MD, M. Gage Ochsner, MD, *and* **David Feliciano, MD,** *Baltimore, Maryland*

BACKGROUND: The operative management of mangled extremities after trauma remains controversial. We have sought to develop an evidence-based algorithm to help guide practitioners when faced with these relatively infrequent but very challenging clinical dilemmas.

METHODS: The Western Trauma Association Critical Decisions Committee queried the literature to identify high-quality managements that would help guide the care of mangled extremities. When good data were not available, the Committee relied on expert opinions, either from the literature or from our senior members.

RESULTS: Virtually, all the scoring systems used to guide therapy have not been proven to be valid. Hemodynamically unstable patients who failed to respond to initial resuscitation should be taken to the operating room for exploration and vascular control. Those who are stable should undergo a stepwise vascular and neurologic evaluation process. A comprehensive evaluation of factors that may help predict the appropriateness of limb salvage should be done in the operating room. Patients who are not candidates for salvage should undergo primary amputation. Those who are should undergo attempts at limb salvage.

CONCLUSIONS: Patients with mangled extremities remain a significant management challenge. This algorithm represents a guideline based on the best evidence available in the literature and expert opinion. It does not establish a standard of care. It should provide a framework for treating physicians and other healthcare professionals to guide therapy, considering individual patients' clinical status and institutional resources. (*J Trauma.* 2012;72: 86–93. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Mangled extremity; amputation; trauma.

Although a precise definition remains elusive, any extremity sustaining sufficiently severe injury to a combination of vascular, bony, soft tissue and/or nerve structures that results in subsequent concern for viability of the limb should be considered a mangled extremity and evaluated appropriately to optimize the potential for functional outcome. Figure 1 and the supporting text comprise an algorithm for making decisions in the management of adult patients who sustain a mangled extremity. In the absence of prospective randomized trials, this algorithm is based on expert opinion and published observational studies. We recognize that variability in decision making will continue based on local resources and local expert consensus opinion. The algorithm and accompanying text are designed to address mangled extremities seen in civilian practice. We recognize military injuries will differ and may require different strategies. Some but not all the principles in this document may be relevant for some battlefield injuries.

The algorithm contains letters A through K, which correspond to lettered text. This text is intentionally concise and its purpose is to navigate the reader through the algorithm and to identify and discuss the gray zones in the logic of this decision making. The annotated algorithm is intended to (a) serve as a quick reference for bedside clinicians, (b) foster more detailed local patient care protocols that will allow for prospective collection of data to identify best practices, and (c) generate research projects to answer specific questions concerning decision making.

It is important to note that our presented algorithm is designed to provide guidance only on the evaluation and treatment of the mangled extremity beginning in the emergency department, and that the prehospital management of these injuries is beyond the scope of this offering. Where possible, known risk factors for adverse outcome have been listed for incorporation in the management decision (Table 1). All listed risk factors are those that have been previously elucidated from the studies available for review. Additional risk factors may also be of undefined importance, including diabetes, antecedent peripheral vascular disease, obesity, and hypercoagulability. Finally, the great majority of data available on mangled extremities has focused on evaluation and treatment of lower limbs with comparatively less described regarding upper extremities. We recognize that loss of an

Submitted: April 20, 2011, Revised: November 9, 2011, Accepted: November 14, 2011.
From the R Adams Cowley Shock Trauma Center (T.M.S., J.D.), University of Maryland Medical Center; Denver Health Medical Center (E.E.M.); San Francisco General Hospital (M.W.); Methodist Hospital (F.A.M.); UC Denver (R.M.); UC Davis Medical Center (C.C.); USCF Fresno (J.D.); Memorial Health Trauma Services (M.G.O.); and Emory University School of Medicine (D.F.).
Presented at the 41st annual meeting of the Western Trauma Association Meeting as a Critical Decisions Paper, February 28–March 3, 2011, Big Sky, Montana.
Address for reprints: Thomas M. Scalea, MD, R. Adams Cowley Shock Trauma Center, 22 South Greene Street, Room P1G01, Baltimore, MD 21201; email: tscalea@umm.edu.

DOI: 10.1097/TA.0b013e318241ed70

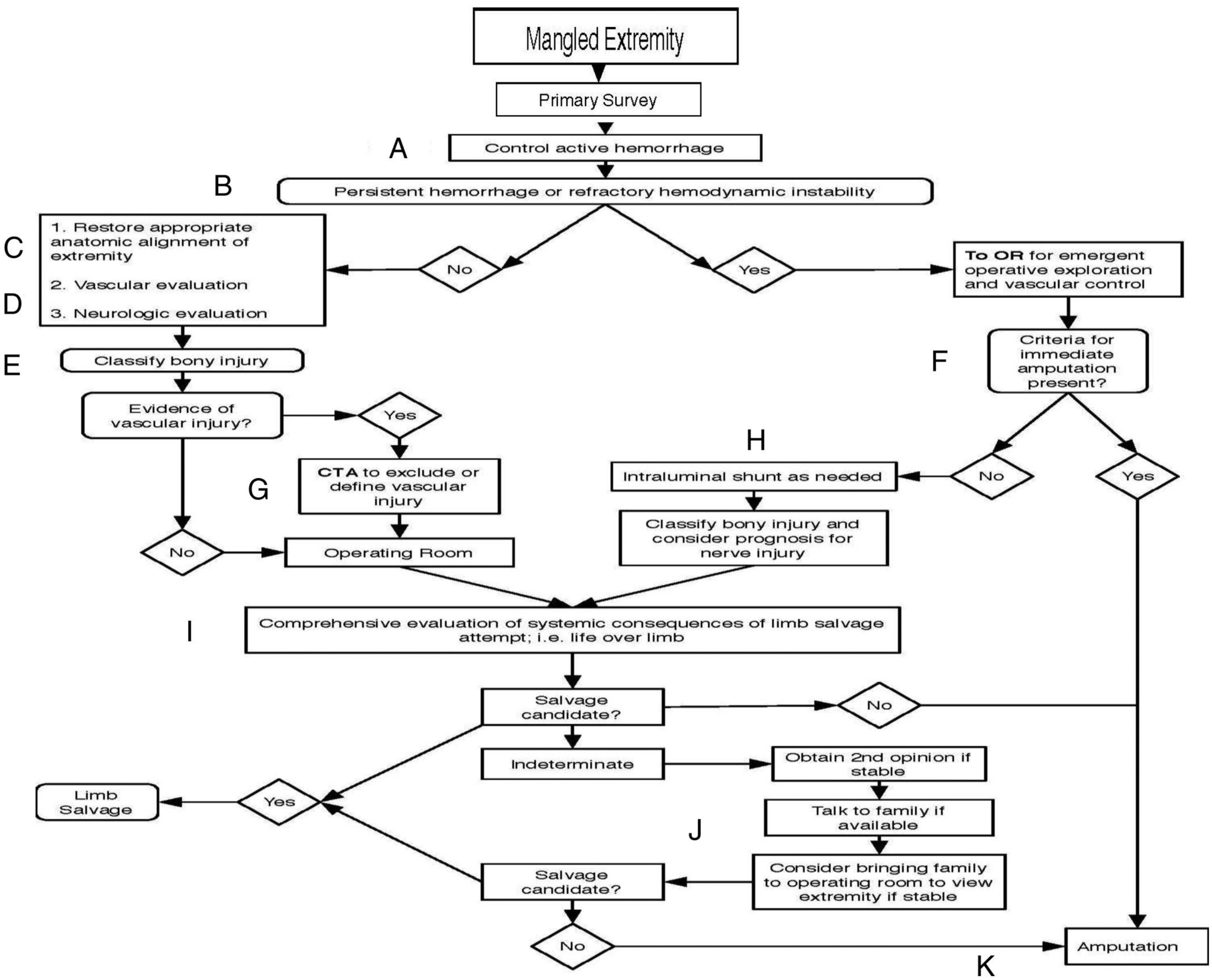

Figure 1. Algorithm for management of patients with mangled extremities.

upper extremity, particularly a dominant upper extremity results in a more severe functional loss then a lower extremity. Emotionally, loss of an upper extremity may be much more difficult than a lower extremity. Thus, more aggressive attempts at limb salvage may be appropriate. However, for the sake of our present algorithm, we do not distinguish between the upper and lower extremities, recognizing that most of the general principles discussed have similar applications regardless of extremity location.

HISTORICAL PERSPECTIVE

The optimal management of patients with mangled extremities after trauma remains controversial. Although these injuries are not common,[1] they represent significant management challenges that require careful consideration of complex clinical factors affecting outcome. Limb salvage efforts require extensive resources and a prolonged hospitalization. Even when successful, multiple reconstruction procedures may be necessary to achieve a good long-term result. Failed attempts at limb salvage are associated with increased cost and adverse patient outcomes. Therefore, the decision process for the care of a mangled extremity requires a systematic approach that adequately considers all factors.

Many predictors of adverse outcome after mangled extremities have been identified,[2–6] and several groups have proposed the use of predictive scoring systems to determine the need for amputation after these injuries[7–14] (Table 2). In 1987, Howe et al.[7] performed a retrospective review of 21 injured limbs to determine which variables influenced salvage or loss after trauma. This group found that a Predictive Salvage Index (PSI), consisting of weighted scoring of the level of vascular injury, degree of osseous injury, degree of muscle injury, and warm ischemia time, was 78% sensitive and 100% specific in predicting subsequent amputation. In

TABLE 1. Predictors Associated With Need for Amputation of Mangled Extremity

Systemic factors
Age >50 yr[3,4,8,11]
High energy transfer mechanism[3,4,8,11]
Persistent hypotension (<90 mm Hg)[3,4,8,11]
Bony skeletal factors
Gustilo type III A fractures with significant tissue loss or nerve injury, associated fibular fracture and displacement of >50%, and comminuted segmental fracture or high probability of bone graft need[7,9,11,14]
Gustilo type III B and III C tibial fractures[7,8,9,11,14]
Type III open fractures of the pilon[7,8,9,11,14]
Type III B open fractures of the ankle[7,8,9,11,14]
Severe open injury to the hindfoot or midfoot[7,8,9,11,14]
Soft tissue factors
Large, circumferential tissue loss[7,8,9,11,14]
Extensive closed soft tissue loss or necrosis[7,8,9,11,14]
Compartment syndrome resulting in myonecrosis[7,8,9,11,14]
Neurologic factors
Confirmed nerve disruption, particularly of tibial nerve[7,9,11,14]
Vascular factors
Prolonged warm ischemia time (>6 h)[3,4,7,9,11,14]
Degree of vascular segment loss[7,9,11,14]
Proximal vascular injury (femoral greater risk than popliteal or more distal)[7,9,11,14]
Absence of viable distal anastomotic site[7,9,11,14]

1990, Johansen et al.[8] proposed the utilization of the Mangled Extremity Severity Score (MESS) which was developed through an examination of 25 patients with severe limb injuries. The MESS consists of four primary risk considerations, including skeletal/soft tissue injury, limb ischemia, shock, and age. These investigators then prospectively validated the score in 26 severely injured limbs, concluding that a MESS of $\geq$7 was 100% predictive of amputation.

A subsequent study conducted by McNamara et al.[4] outlined the development and utilization of a nerve injury, ischemia, soft tissue injury, skeletal injury, shock, and age of patient (NISSSA) score, which added consideration of the nerve component of injury. The NISSSA score gave the greatest weight to the loss of plantar sensation and also divided tissue injury into soft tissue and skeletal components. In 26 injured limbs, the NISSA score was found to be both more sensitive (81.8% vs. 63.6%) and more specific (92.3% vs. 69.2%) than the MESS. Other scoring systems, including the Limb Salvage Index (LSI) proposed by Russell et al. in 1991[9] and the Hannover Fracture Scale[11] have also been used to predict the need for amputation after trauma.

All these scoring systems, however, have failed to prove their validity in larger prospective examinations. In 2001, Bosse et al.[14] conducted a prospective evaluation of available scoring systems in an examination of 556 high-energy lower-extremity injuries. They examined the sensitivity, specificity, and area under the receiver operating characteristic curve for MESS, LSI, PSI, NISSSA score, and the Hannover Fracture Scale for both ischemic and nonischemic limbs. Their analysis was conducted in two ways: including and excluding limbs that required immediate amputation. These investigators were unable to demonstrate the validity of these scoring systems. Although all had high specificity for prediction of limb salvage when the scores were low, the sensitivity of the indices failed to support the validity of any scoring system as an adequate predictor of amputation.[14] Ly et al. and the LEAP study group[10] would follow this investigation, in 2008, with analysis of a cohort of patients who participated in a multicenter prospective study of clinical and functional outcomes after high-energy lower extremity trauma. They examined 407 subjects for whom reconstruction was considered successful at six months and found that none of the retrospectively validated scoring systems (MESS, LSI, PSI, NISSSA score, or the Hannover Fracture Scale) were predictive of the Sickness Impact Profile outcomes at six months or 24 months. In addition, none of these scoring systems predicted patient recovery between six months and 24 months. They concluded that no currently available Injury Severity Score was predictive of functional recovery of patients who undergo successful limb reconstruction.

TABLE 2. Historically Used Individual Scoring Systems to Evaluate the Mangled Extremity

Scoring System	Reference	Identified Risk Factors for Amputation/ Adverse Outcome
Predictive Salvage Index (PSI)	Howe et al.[7]	Level of vascular injury
		Warm ischemia time
		Quantitative degree of muscle, bone and skin injury
Mangled Extremity Severity Score (MESS)	Johansen et al.[8]	Degree of skeletal and soft tissue damage
		Limb ischemia
		Shock
		Age
Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age of Patient Score (NISSA)	McNamara et al.[4]	Limb ischemia
		Hypotension
		Age
		Skeletal injury
		Soft tissue injury
		Nerve injury
Limb Salvage Index (LSI)	Russell et al.[9]	Arterial injury
		Nerve injury
		Bone injury
		Skin injury
		Muscle injury
		Deep venous injury
		Warm ischemia time
Hanover Fracture Scale (HFS)	Tscherne and Oestern[11]	Bone loss
		Skin injury
		Muscle injury
		Wound contamination
		Nerve injury
		Periosteal stripping
		Vascular injury
		Hypotension

In the absence of an adequate scoring system, the management of the patient with a mangled extremity requires a multidisciplinary approach and careful consideration of complex systemic and limb-related factors. Optimal outcome requires the trauma provider to evaluate these factors systematically to determine the appropriate choice between limb salvage procedures and amputation.

ALGORITHM TEXT

The issues addressed in this management algorithm are diagnostic evaluation, indications for emergent amputation, and critical decisions regarding the viability of the limb and potential for limb salvage. Mangled extremities almost by definition involve Gustilo type III B or III C injuries (Table 3). Many of these determinations will be greatly influenced by the availability of resources, the expertise available, and factors that may well vary from institution to institution.

It is important to stress that the initial evaluation of a patient with a mangled extremity does not differ from that of any other patients with multiple injuries. The initial ABC's of evaluation take precedence. Providers must resist the temptation to become diverted by the graphic appearance of the extremity and maintain a systematic approach that focuses on the detection and effective treatment of more serious issues. The only immediately life-threatening aspect of the extremity is external blood loss. An ischemic limb does not represent an immediate threat to life. It is a common pitfall, among inexperienced providers, to reach for the Doppler probe in an effort to assess distal perfusion as a component of the primary survey. This practice may result in the delayed diagnosis of truncal hemorrhage, brain injury, or other immediately life-threatening conditions.

Without an algorithmic approach to the mangled extremity, errors in management may occur. Typical errors that might occur include failure to accomplish timely reperfusion of ischemic tissue, delays associated with ineffective communication between senior surgeons from the necessary specialties, unnecessary delays because of inappropriate vascular imaging requests, inadequate debridement and fracture stabilization, and delays in soft tissue coverage attempts.

A. Control of ongoing blood loss should be initiated on arrival. Direct control of ongoing hemorrhage via manual pressure or a pressure dressing should be undertaken expeditiously. If ongoing life-threatening hemorrhage cannot be controlled through the use of direct pressure, early use of tourniquet may prove life saving in the prevention of serious additional bleeding from the limb.[15,16] Tourniquet use will be most successful in distal limb injuries. It should be used as a temporizing measure to aid resuscitation and allow rapid diagnostics, but should be kept to the shortest duration possible to minimize the possibility of worsening ischemia. Operative tourniquet systems, commonly used during operative orthopedic procedures, are preferable to field tourniquets whenever available. It is advisable to provide appropriate inflation of these pneumatic devices, because pressures below systolic may substantially increase venous pressure (creating a "venous tourniquet"), worsen subsequent extremity swelling, and potentially increase pressure within the muscular compartments of the extremity without affecting the desired occlusion of arterial hemorrhage.

Level of Supporting Evidence: Level 4

B. If external bleeding cannot be controlled or the patient remains unstable without other source despite adequate efforts in the emergency department, the patient should be taken expeditiously to the operating room for surgical control of bleeding. If the patient has concomitant intracavitary hemorrhage, it may be advantageous to use two operative teams. If not, tourniquet use may temporarily control extremity hemorrhage until cavitary sources of ongoing blood loss are managed. Initial control of truncal hemorrhage using damage control techniques will allow the extremity to be addressed as early as possible.

Level of Supporting Evidence: Level 4

C. In the patient who remains hemodynamically stable, the most important initial step is to reduce the fractured bones using either splinting or traction fixation. This will alleviate kinking of the vasculature and improve subsequent perfusion and permit better assessment of the bony and soft tissue abnormalities. Adequate analgesia is crucial to achieving good bony alignment in a humane manner. Repeat doses of fentanyl, in 25 microgram IV aliquots, may facilitate the performance of bony manipulation. When using this approach, blood pressure and respiratory status should be assessed at regular intervals to insure that cardiorespiratory depression because of narcotic use is avoided. Induction of anesthesia and endotracheal intubation may be required.

Level of Supporting Evidence: Level 4

D. Blunt vascular extremity injuries may be associated with the need for amputation in as much as 20% of patients.[17] Among patients with multiple injuries because of blunt mechanisms, competing priorities of initial treatment may delay diagnosis of extremity vascular injury. In addition, pulse examination alterations are common sequelae of displaced

TABLE 3. Gustilo Open Fracture Classification System

Gustilo type I
Wound less than 1 cm with minimal soft tissue injury
Wound bed is clean
Fracture is transverse or short oblique fracture with minimal comminution
Gustilo type II
Wound is greater than 1 cm with moderate soft tissue injury
Fracture simple transverse or short oblique fracture, with minimal comminution
Gustilo type III A
Soft tissue coverage facilitated by primary suture closure despite soft tissue laceration, flaps, or high-energy trauma; irrespective of wound size
Includes segmental fractures or severely comminuted fractures
Gustilo type III B
Extensive soft tissue loss with periosteal stripping and bony exposure; most commonly requiring local or free flap coverage
Usually associated with massive contamination
Gustilo type III C
Extensive fracture associated with major arterial injury requiring repair for limb salvage

fractures in these patients. An early vascular assessment will permit for the rapid identification of these injuries and minimize subsequent ischemic time. After restoration of anatomic alignment and adequate resuscitation, this examination should begin with an attempt to palpate the pulse. If the pulse is not palpable, or weaker than anticipated, then an attempt at bedside Doppler assessment should be undertaken. If a Doppler assessment reveals a signal and tissue loss does not preclude measurement, an Ankle-Brachial Index or Brachial-Brachial Index can be used to guide the need for additional vascular imaging.[18–20] Doppler indices less than 0.9 or absent/diminished pulse in the affected extremity indicate the need for additional radiographic characterization in appropriately stable patients[20] (see G).

Both Ankle-Brachial Indexes and Brachial-Brachial Indexes can be altered by a number of factors not directly related to vascular injury, including obesity, hypotension, and peripheral vascular construction because of hypothermia or hemorrhage. It is imperative to use blood pressure cuffs for this purpose that are appropriately sized to patient body habitus. Efforts should also be taken to adequately resuscitate and warm the patient to optimize the reliability of Doppler Indices.

Level of Supporting Evidence: Level 3

E. An adequate neurologic examination of the extremity to assess peripheral nerve function should be conducted. Nerve deficits, particularly tibial nerve, are thought to portend a dire functional outcome. Signs of specific nerve injuries are listed in Table 4. Prospective study,[10] however, has demonstrated that peripheral nerve deficits are not sensitive predictors for failure of functional limb salvage. This finding may be reflective of the unpredictable natural course of many of these injuries. Differentiating neuropraxia, or temporary deficits, from permanent nerve injury in the acute phases after injury may prove difficult. It is important to document these findings, however, and factor their presence into the decision-making process.

Level of Supporting Evidence: Level 4

F. In patients who require emergent operative therapy to address ongoing hemorrhage from the extremity or other sources, careful consideration should be given to the appropriateness of limb salvage. Familiarity with the factors associated with poor outcome of a mangled extremity (Table 1) can assist in the decision-making process in these instances.[2,3,4–9,21–24] The stratification of the relative importance of these risk factors, as outlined in "Historical Perspective," above, is difficult because of the absence of conclusive data. Other potential risk modifiers, including diabetes, peripheral vascular disease, smoking history, obesity, and hypercoagulability should also be considered in management decisions.

Sometimes, the decision is clear, for example, a limb that is attached only by skin and subcutaneous tissue. Other cases are not as clear. In these cases, beginning an attempt at limb salvage is reasonable. If further evaluation deems limb salvage not wise, amputation can be completed at that time. In the patients with severe multiple injuries, an extremity that might be salvageable as an isolated injury may represent an additional injury burden that the patient will not tolerate when considered in to. In such cases, primary amputation allows the surgeon to concentrate on more pressing injuries. The condition of the patient and the constellation of associated injuries must be considered carefully in these "life over limb" situations.

TABLE 4. Peripheral Nerve Injury Findings

Lower extremity
Femoral nerve
Motor: inability to extend the lower extremity at the knee
Sensory: numbness over distal 1/3 of the anteromedial aspect of the thigh
Peroneal nerve injury
Motor:
Common peroneal: weakness or inability to dorsiflex foot and toes, as well as foot eversion ("foot drop")
Deep peroneal: weakness or inability to dorsiflex foot and toes
Superficial peroneal: inability to evert foot
Sensory:
Deep peroneal: decreased or absent sensation dorsal web space between 1st and second toes
Superficial peroneal: decreased or absent sensation remainder of dorsal foot
Tibial nerve injury
Motor: weakness or absence of toe plantar-flexion or foot inversion (foot plantar flexion by Achilles-gastroc-soleus)
Sensory: numbness over sole and heel of the foot
Upper extremity
Median nerve
Motor: weak or absent flexion of thumb and index finger IP joints against resistance
Sensory: decreased or absent sensation palmar surface of thumb, index and middle fingers
Radial nerve
Motor: weak or absent dorsiflexion of wrist and/or thumb
Sensory: decreased or absent sensation in dorsal web space between thumb and index fingers
Ulnar nerve
Motor: weakness or absence of finger abduction and adduction
Sensory: decreased or absent sensation little finger and ulnar half of ring finger

Good communication with the anesthesiology team throughout the operative intervention is paramount to optimizing outcome. Aggressive resuscitation may be required in these cases; to such an extent that sequela of considerable fluid resuscitation, including secondary abdominal compartment syndrome, may manifest precipitously. Optimizing communication with anesthesiology colleagues will alert the surgeon to these potential issues and prevent focus on the extremity from delaying recognition that aggressive resuscitative needs are indicative of bleeding source elsewhere.

Level of Supporting Evidence: Level 4

G. In the stable patient with evidence of vascular injury on examination, additional imaging should be obtained to characterize the location and nature of the injury. Computed tomographic angiography (CTA) has emerged as the primary evaluation tool at many trauma centers. If feasible, CTA should be included in the initial CT screening of these patients. The sensitivity and specificity of this modality has proven comparable with traditional angiography in the detection of vascular injury[25–27] and the rapidity with which it can be obtained assists in limiting ischemic time.

In the ischemic limb, it is important to consider the potential delays that may be associated with the choice of diagnostic imaging. In many centers, extremity CTA adds ~20 minutes to the imaging time of a patient with multiple injuries. The patient must be brought out of the gantry, turned around, and placed back into the gantry to obtain the CTA. Utilization of traditional angiography may be associated with even more substantial logistical challenges. The surgeon must weigh carefully the need for vascular evaluation against the cost to the individual patient in terms of delay and contrast load risks.

If CTA is not available, traditional or intraoperative angiography can be used to identify and exclude vascular injury in the mangled extremity.[28] Angiography can provide a dynamic assessment of the vasculature. This allows the surgeon to visualize the vascular injury, the adequacy of collateral flow, and back filling of vessels. Traditional angiography can be time consuming, however, if performed in the angiogram suite. Newer hybrid operating rooms may decrease the interval to diagnosis of the vascular injury, even allow for this imaging to be performed as the operating team begins the exploration.

In most centers, direct operative exploration may provide for the most expedient identification and treatment of injury. Intraoperative angiography can be used to assess the adequacy of the distal vasculature as an adjunct of emergent operative intervention if appropriate facilities and expertise are available.

Level of Supporting Evidence: Level 2A

H. Intraluminal shunts can be used as a temporizing measure to restore distal perfusion to the affected extremity, while the remainder of the evaluation is being conducted, or during bony evaluation/fixation.[29–32] Shunts have been successfully used as a temporizing bridge to definitive vascular repair even in the setting of contraindications to anticoagulation.[33] Some shunts, including the Pruiit-Inahara shunt, have a third arm that is particularly useful in effectively facilitating the intravascular administration of local anticoagulants and vasoactive medications. The use of shunts may particularly prove useful when long segment vascular loss is identified or in the setting of hemodynamic instability precluding extensive vascular repair at the initial operation. After the shunt is inserted, the surgeon should document flow to the distal extremity with a palpable pulse, Doppler signal, or an angiogram.

Level of Supporting Evidence: Level 4

I. Definitive evaluation of a mangled extremity should universally be completed in the operating room. In this setting, the patient can be resuscitated and additional diagnostics performed, including radiographic bony evaluation using plain films or fluoroscopy, on-table angiography, and direct examination of the soft tissues and anatomic structures. The factors influencing the decision to attempt limb salvage or proceed with amputation are complex. These include systemic, bony skeletal, soft tissue, nerve, and vascular factors (Table 1, Table 2, and Table 3). The evaluation of these factors should repeatedly be weighed against the overall patient injury burden to insure that limb evaluation and salvage efforts are not counter to the efforts to sustain the life and overall patient outcome.

The degree of soft tissue debridement needed is an important factor in deciding on the advisability of limb salvage and/or the level of amputation. Circumferential loss of soft tissue makes limb salvage less attractive. Vascular and bony structures require soft tissue coverage. The more extreme the loss of soft tissue, the fewer the options for this coverage. The level of amputation needed is another important decision. Salvaging a below knee amputation makes the patient far more functional than if an above knee amputation is needed. Longer above knee amputation stumps are preferable to shorter ones. Transfemoral amputations are far more functional than hip disarticulations. The integrity of soft tissue is often critical in this decision making. Overall, a well-constructed longer residual limb will prove more functional and, when possible, reconstructive procedures may permit subsequent salvage of a lower level of amputation to improve ultimate function.

Consultation from orthopedic and/or microvascular reconstructive surgeons may be helpful in providing additional innovative options including free tissue transfer to help salvage a more functional amputation level. Although consultation may often be helpful, it is important that the general trauma surgeon remain in charge and act as "captain of the ship." Consultants offer expertise about a specific anatomic area and/or facet of the problem. However, only the general surgeon has responsibility for the entire patient and has the best overall understanding of total patient physiology. Occasionally, complicated solutions may be possible and attractive to a subspecialist but not be the best overall plan for the patient. In particular, decisions about the appropriateness of limb salvage should remain the general surgeon's responsibility to avoid attempts at limb salvage that may put the patient's life in jeopardy.

Level of Supporting Evidence: Level 4

J. The loss of a limb represents a significant psychologic, social, economic, and life-style burden that should not be underestimated. Whenever possible, it is advisable to incorporate the patient and/or their family in the decision process regarding limb salvage versus amputation. Full disclosure regarding the thought process and consideration factors should be provided to the consenting parties. Even in emergent situations, where the loss of limb is necessary to sustain life (life vs. limb), the earliest possible communication with the family is paramount.

When patient stability permits, some senior surgeons have adopted policies that permit family members to come to the operating room to examine the limb with the treatment team, so that they are incorporated into the decision process at the earliest stages after injury. Alternatively, the operating team can take operative photos to the family waiting room. Although this may seem unkind, it certainly provides a graphic understanding as to why amputation would be wise. Although we do not advise this as a routine policy for all trauma centers, we offer it as an option. It is important to be clear and honest with the family. Their tendency will be to opt for limb salvage. It is not wise to offer that as an option if the surgeon does not think that it is the wisest course of action for the patient. Finally, some surgeons may opt to place operative photos into the medical record. This documents the degree of injury and may be helpful later to reemphasize the need for amputation to the patient and family. These photos may also be helpful if allegations of malpractice are brought against the surgeon.

Level of Supporting Evidence: Level 4

SUMMARY

Patients with mangled extremities remain a significant management challenge. A thoughtful approach to the management has the potential to optimize outcome after these injuries. The algorithm above represents the efforts of the Western Trauma Association Critical Decisions in Trauma Ad Hoc Committee based on best evidence available and expert opinion. Prospective validation of this algorithm is advised.

The Western Trauma Association (WTA) develops algorithms to provide guidance and recommendations for particular practice areas but does not establish the standard of care. The WTA develops algorithm based on the evidence available in the literature and the expert opinion of the task force in the recent timeframe of the publication. The WTA considers use of the algorithm to be voluntary. This tool may, however, prove a useful discussion tool for multidisciplinary review of institutional protocols. The ultimate determination regarding its application is to be made by the treating physician and health care professionals with full consideration of the individual patient's clinical status and available institutional resources and is not intended to take the place of health care providers' judgment in diagnosing and treating particular patients.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Barmparas G, Inaba K, Teixeira PG, et al. Epidemiology of post-traumatic limb amputation: a National Trauma Databank analysis. *Am Surg.* 2010;76:1214–1222.
2. Prichayudh S, Verananvattna A, Sriussadaporn S, et al. Management of upper extremity vascular injury: outcome related to the Mangled Extremity Severity Score. *World J Surg.* 2009;33:857–863.
3. Helfet DL, Howey T, Sanders R, Johansen K. Limb salvage versus amputation. preliminary results of the Mangled Extremity Severity Score. *Clin Orthop Relat Res.* 1990;256:80–86.
4. McNamara MG, Heckman JD, Corley FG. Severe open fractures of the lower extremity: A retrospective evaluation of the Mangled Extremity Severity Score (MESS). *J Orthop Trauma.* 1994;8:81–87.
5. Slauterbeck JR, Britton C, Moneim MS, Clevenger FW. Mangled extremity severity score: an accurate guide to treatment of the severely injured upper extremity. *J Orthop Trauma.* 1994;8:282–285.
6. Gregory RT, Gould RJ, Peclet M, et al. The mangled extremity syndrome (M.E.S.): a severity grading system for multisystem injury of the extremity. *J Trauma.* 1985;25:1147–1150.
7. Howe HR Jr, Poole GV Jr, Hansen KJ, et al. Salvage of lower extremities following combined orthopedic and vascular trauma. A Predictive Salvage Index. *Am Surg.* 1987;53:205–208.
8. Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma.* 1990;30:568–572; discussion 572–573.
9. Russell WL, Sailors DM, Whittle TB, Fisher DF Jr, Burns RP. Limb salvage versus traumatic amputation. A decision based on a seven-part predictive index. *Ann Surg.* 1991;213:473–480; discussion 480–481.
10. Ly TV, Travison TG, Castillo RC, Bosse MJ, MacKenzie EJ; LEAP Study Group. Ability of lower-extremity injury severity scores to predict functional outcome after limb salvage. *J Bone Joint Surg Am.* 2008;90:1738–1743.
11. Tscherne H, Oestern JH. [A new classification of soft-tissue damage in open and closed fractures]. *Unfallheilkunde*. 1982;85:111–115.
12. Togawa S, Yamami N, Nakayama H, Mano Y, Ikegami K, Ozeki S. The validity of the Mangled Extremity Severity Score in the assessment of upper limb injuries. *J Bone Joint Surg Br.* 2005;87:1516–1519.
13. Cannada LK, Cooper C. The mangled extremity: limb salvage versus amputation. *Curr Surg.* 2005;62:563–576.
14. Bosse MJ, MacKenzie EJ, Kellam JF, et al. A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. *J Bone Joint Surg Am.* 2001;83-A:3–14.
15. Kragh JF Jr, Walters TJ, Baer DG, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg.* 2009;249:1–7.
16. Beekley AC, Sebesta JA, Blackbourne LH, et al; 31st Combat Support Hospital Research Group. Prehospital tourniquet use in operation iraqi freedom: effect on hemorrhage control and outcomes. *J Trauma.* 2008;64(2 suppl):S28–S37; discussion S37.
17. Rozycki GS, Tremblay LN, Feliciano DV, McClelland WB. Blunt vascular trauma in the extremity: diagnosis, management, and outcome. *J Trauma.* 2003;55:814–824.
18. Mills WJ, Barei DP, McNair P. The value of the ankle-brachial index for diagnosing arterial injury after knee dislocation: a prospective study. *J Trauma.* 2004;56:1261–1265.
19. Nassoura ZE, Ivatury RR, Simon RJ, Jabbour N, Vinzons A, Stahl W. A reassessment of Doppler pressure indices in the detection of arterial lesions in proximity penetrating injuries of extremities: a prospective study. *Am J Emerg Med.* 1996;14:151–156.
20. Feliciano DV. Management of peripheral arterial injury. *Curr Opin Crit Care.* In press.
21. Lin CH, Wei FC, Levin LS, Su JI, Yeh WL. The functional outcome of lower-extremity fractures with vascular injury. *J Trauma.* 1997;43:480–485.
22. Bernstein ML, Chung KC. Early management of the mangled upper extremity. *Injury.* 2007;38 suppl 5:S3–S7.
23. O'Sullivan ST, O'Sullivan M, Pasha N, O'Shaughnessy M, O'Connor TP. Is it possible to predict limb viability in complex Gustilo IIIB and IIIC tibial fractures? A comparison of two predictive indices. *Injury.* 1997;28:639–642.
24. Rajasekaran S, Naresh Babu J, Dheenadhayalan J, et al. A score for predicting salvage and outcome in Gustilo type-IIIA and type-IIIB open tibial fractures. *J Bone Joint Surg Br.* 2006;88:1351–1360.
25. Pieroni S, Foster BR, Anderson SW, Kertesz JL, Rhea JT, Soto JA. Use of 64-row multidetector CT angiography in blunt and penetrating trauma of the upper and lower extremities. *Radiographics.* 2009;29:863–876.
26. Peng PD, Spain DA, Tataria M, Hellinger JC, Rubin GD, Brundage SI. CT angiography effectively evaluates extremity vascular trauma. *Am Surg.* 2008;74:103–107.
27. Seamon MJ, Smoger D, Torres DM, et al. A prospective validation of a current practice: the detection of extremity vascular injury with CT angiography. *J Trauma.* 2009;67:238–243; discussion 243–244.

28. Callcut RA, Acher CW, Hoch J, Tefera G, Turnipseed W, Mell MW. Impact of intraoperative arteriography on limb salvage for traumatic popliteal artery injury. *J Trauma.* 2009;67:252–257; discussion 257–258.
29. Hossny A. Blunt popliteal artery injury with complete lower limb ischemia: Is routine use of temporary intraluminal arterial shunt justified? *J Vasc Surg.* 2004;40:61–66.
30. Gifford SM, Aidinian G, Clouse WD, et al. Effect of temporary shunting on extremity vascular injury: an outcome analysis from the global war on terror vascular injury initiative. *J Vasc Surg.* 2009;50:549–555; discussion 555–556.
31. Bowley DM, Degiannis E, Goosen J, Boffard KD. Penetrating vascular trauma in Johannesburg, South Africa. *Surg Clin North Am.* 2002;82:221–235.
32. Subramanian A, Vercruysse G, Dente C, Wyrzykowski A, King E, Feliciano DV. A decade's experience with temporary intravascular shunts at a civilian level I trauma center. *J Trauma.* 2008;65:316–324; discussion 324–326.
33. Granchi T, Schmittling Z, Vasquez J, Schreiber M, Wall M. Prolonged use of intraluminal arterial shunts without systemic anticoagulation. *Am J Surg.* 2000;180:493–496; discussion 496–497.