The Mangled Extremity: When Should It Be Amputated?

Douglas R. Dirschl, MD, and Laurence E. Dahners, MD

Abstract

Amputation of a mangled extremity is repugnant to the patient and the surgeon. However, prolonged unsuccessful attempts at salvage are costly, highly morbid, and sometimes lethal. Much discussion has taken place regarding which criteria predict successful salvage, and predictive indices have been proposed in an attempt to identify limbs for which attempted salvage is unlikely to succeed. The Mangled Extremity Severity Score, or MESS, system is the most thoroughly validated of the various classification systems, but at present there is no predictive scale that can be used with confidence to determine whether to amputate or attempt to salvage a mangled lower extremity. Therefore, these systems should serve only as guides to supplement the surgeon's clinical judgment and experience. Although salvage for severe injuries below the knee can be difficult and the functional outcome unpredictable, prosthetic function after transtibial amputation is generally good. Conversely, prosthetic function after transfemoral or transradial amputation is often poor, while salvage of some useful function for injuries above the knee is often successful. When limb loss is inevitable, immediate amputation is desirable. If obvious criteria for primary amputation are not met, however, it is reasonable to consider an initial salvage attempt, observation, and subsequent early secondary amputation.

J Am Acad Orthop Surg 1996;4:182-190

The use of guidelines to aid in the decision for salvage versus amputation of severely injured extremities is far from new. During the Civil War, Frank Hastings Hamilton recommended amputation after a gunshot fracture if any of the following conditions existed: (1) the patient had to be carried over rough roads; (2) the bones were greatly comminuted; (3) the patient suffered great pain; (4) the soft parts had suffered great contusion; (5) there was extensive laceration; (6) the principal arteries or nerves were involved; or (7) the type of fracture involved the knee or ankle joint.[1] In 1943, Kirk[2] defined the general indications for amputation as any injury, disease, or deformity rendering the retention of the limb incompatible with life or function.

Recent advances in trauma management, vascular reconstruction, nerve grafting, and revascularized-tissue transfer have dramatically extended the surgeon's ability to salvage a mangled limb. These advances have fostered the attitude that amputation represents a therapeutic failure and have led to costly, highly morbid, and sometimes lethal attempts at preservation of functionless limbs. In an editorial preceding a series reporting on the results of treatment of open tibial fractures with vascular injuries, Hansen[3] concluded that the functional and cosmetic results of an attempt at salvage are often worse than those of early amputation, leaving the patient demoralized, divorced, and / or destitute.

There is ongoing debate regarding the criteria that predict successful salvage of severely injured extremities, and predictive indices have been devised in an attempt to identify limbs for which attempted salvage is unlikely to succeed.[4-9] These scoring systems have been criticized, however, as being too complex, subjective, and difficult to apply in a prospective fashion; derived from relatively small patient populations; and not validated by functional outcome data. The high cost of limb salvage compared with that of early amputation has also entered the discussion

Dr. Dirschl is Assistant Professor, Department of Orthopaedics, University of North Carolina School of Medicine, Chapel Hill. Dr. Dahners is Professor, Department of Orthopaedics, University of North Carolina School of Medicine, Chapel Hill.

Reprint Requests: Dr. Dirschl, Wake Medical Education Institute, Department of Orthopaedics, 3024 New Bern Avenue, Suite 302, Raleigh, NC 27610.

regarding treatment of these injuries. Finally, there are potential medicolegal issues involved in the decision for early amputation of a traumatized extremity.

In this article, we review the mechanisms and patterns of injury associated with mangled extremities and discuss the strengths, weaknesses, and clinical validation of published scoring systems. We also compare the functional outcomes and costs of limb salvage and amputation and make recommendations for decision making in the treatment of patients with mangling injuries to the upper and lower extremities. We will not address the orthopaedic and microsurgical techniques involved in limb salvage or amputation.

Basic Principles

The vast majority of mangled extremities in the literature are the result of blunt trauma. Motor-vehicle crashes and industrial accidents are the most frequent causes in the lower extremity. The single published series of mangling injuries to the upper extremity did not report the mechanism of injury.[10] More important than how the injury occurs, however, is the amount of energy transmitted to the bone and soft tissues. Low-velocity gunshot injuries cause much less damage than crushing or shearing injuries. This has led to the concept of the "zone of injury," defined as the entire expanse of the extremity affected by the injuring force. This may involve comminution of bone, crushing or shearing of soft tissues, or devascularization of an entire limb. Although most easily identified, the skeletal injury is not the most significant factor determining viability and functional potential; vascular, neurologic, and especially soft-tissue injuries play a much larger role in predicting the survival and ultimate function of a mangled extremity.

A mangled upper extremity has a much greater impact on the overall function of the patient than does a mangled lower extremity, and the goals of salvage are therefore much different. For example, 2 cm of shortening of the humerus has much less effect on function than an equal amount of shortening of the tibia. Likewise, the results of nerve repair are better in the upper than in the lower extremity, and the functional prognosis for a patient with a transtibial prosthesis is much better than that for a patient with a transradial prosthesis. Because the goals and results of salvage in the upper and lower limbs are different, the criteria for salvage should also be different.[11]

Table 1
Indications for Primary Amputation After Open Tibial Fractures with Vascular Injury*

Absolute indications
- Anatomically complete disruption of the posterior tibial nerve in an adult
- Crush injury with warm ischemia time >6 hr

Relative indications
- Serious associated polytrauma
- Severe ipsilateral foot trauma
- Anticipated protracted course to obtain soft-tissue coverage and tibial reconstruction

*Adapted with permission from Lange RH, Bach AW, Hansen ST Jr, et al: Open tibial fractures with associated vascular injuries: Prognosis for limb salvage. *J Trauma* 1985;25:203-208.

Classification Systems

Indications of Lange et al

In 1985, Lange et al[4] published absolute and relative indications for amputation after an open tibial fracture with vascular injury (Table 1). They specified that primary amputation was indicated if either of the absolute indications or two of the three relative indications were present. No subsequent clinical studies were performed to validate this classification scheme.

Mangled Extremity Syndrome Index

In 1985, Gregory et al[5] published the first scoring system for severely injured extremities, the Mangled Extremity Syndrome Index (MESI). This system combines point scales for the degree of integumentary, nervous, vascular, and osseous injury with point scales to quantify the injury severity score, age, preexisting medical condition, and length of time to vascular repair (Table 2). In the initial retrospective series, 100% of patients with a MESI greater than 20 required amputation. Unfortunately, only 12 of the 17 cases involved the lower extremity, and the series included an unspecified number of primary amputations.

The MESI is quite complex and requires the physician to have complete knowledge of all the patient's injuries, which may not be possible at the time of initial treatment. In addition, some of the elements of the MESI are subjective, and scores may therefore vary from observer to observer. Its complexity makes it difficult to apply on a regular basis and has hindered its widespread acceptance and application.

In two studies, authors retrospectively applied the MESI to patients in their series. In the first study, Roessler et al[12] found that many MESI scores were only approximate because all of the necessary information was not available. When a score of 20 points or

Table 2
Mangled Extremity Syndrome Index*

Criterion	Score
Injury severity score	
<25	1
25-50	2
>50	3
Integument injury	
Guillotine	1
Crush / burn	2
Avulsion / degloving	3
Nerve injury	
Contusion	1
Transection	2
Avulsion	3
Vascular injury	
Vein transected	1
Artery transected	1
Artery thrombosed	2
Artery avulsed	3
Bone injury	
Simple	1
Segmental	2
Segmental comminuted	3
Bone loss <6 cm	4
Articular	5
Articular with bone loss >6 cm	6
Lag time to operation†	. . .
Age, yr	
<40	0
40-50	1
50-60	2
>60	3
Preexisting disease	1
Shock	2

*Adapted with permission from 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.
†One point is given for each hour over 6 hr.

greater was used as a predictor of amputation, the MESI predicted amputation in five patients who had successful limb salvage and salvage in four patients who ultimately required amputation.

In the second study, Bonanni et al[13] found that the MESI predicted amputation with a sensitivity of 6% and a specificity of 90%. They concluded that the MESI contained many variables that necessitated surgical intervention for accurate determination, making it impossible to accurately apply the scoring system.

Predictive Salvage Index

In 1987, Howe et al[6] introduced the Predictive Salvage Index (PSI) for use in patients with combined orthopaedic and vascular injuries of the lower extremity. Less complicated than the MESI, the PSI system assigns points for the level of arterial injury, the degree of bone injury, the degree of muscle injury, and the interval between injury and arrival in the operating room (Table 3). As with the MESI, some of the information necessary for determining the PSI, such as the level of arterial injury, may not be available in the emergency department.

In the initial retrospective analysis of 21 patients, all 12 in the salvage group had a PSI of less than 8, while 7 of 9 in the amputation group scored at least 8. Howe et al concluded that the PSI predicted amputation with a sensitivity of 78% and a specificity of 100%. These conclusions must be qualified by the spectrum of injuries included in their study (five femoral fractures, 12 tibial fractures, two disruptions of the symphysis pubis, and one knee dislocation).

Applying the PSI retrospectively to their data, Bonanni et al[13] found that the PSI predicted amputation with a sensitivity of 33% and a specificity of 70%. Roessler et al[12] found that the PSI predicted amputation for two patients in whom salvage was successful and predicted salvage for five patients in whom amputation was eventually required.

Table 3
Predictive Salvage Index System*

Criterion	Score
Level of arterial injury	
Suprapopliteal	1
Popliteal	2
Infrapopliteal	3
Degree of bone injury	
Mild	1
Moderate	2
Severe	3
Degree of muscle injury	
Mild	1
Moderate	2
Severe	3
Interval from injury to operating room, hr	
<6	0
6-12	2
>12	4

*Adapted with permission from 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.

Mangled Extremity Severity Score

In 1990, Johansen et al[7] proposed the Mangled Extremity Severity Score (MESS) system, which is based on four clinical criteria: skeletal and soft-tissue injury, ischemia, shock, and age (Table 4). The MESS system was based on a retrospective review of 26 mangled lower extremities. It was validated in a prospective trial involving 26 patients treated at a separate trauma center. In both trials, a MESS of less than 7 predicted salvage with 100% accuracy.[7,14]

The MESS system is the simplest to apply and the most thoroughly validated of the mangled extremity scoring systems. In nearly all cases, the information necessary for scoring is available at the time of initial evaluation. One criticism of the system, however, is that the differentiation between high-energy and very-high-energy injuries is based, in part, on the presence of gross contamination, which is largely a subjective determination.

Robertson[15] performed a retrospective review of the data on 152 patients with open fractures of the lower extremity that required vascular or soft-tissue reconstruction. All patients with a MESS of 7 or more eventually underwent amputation, while all 43 patients whose limbs were ultimately salvaged had a score of less than 7. Of the 65 patients who underwent delayed amputation, however, only 16 had a MESS of 7 or more at the time of initial evaluation. The authors concluded that the MESS system had a 100% specificity but lacked sensitivity.

Bonanni et al[13] found that the MESS system predicted amputation with a sensitivity of 22% and a specificity of 53%. They concluded, however, that, although the system reduced the complexity encountered with use of the MESI and PSI, it was not as simple or as sensitive as it appeared.

McNamara et al[9] retrospectively applied the MESS system to 33 patients with grade III open fractures of the tibia and noted a significant difference between the mean MESS of the amputation group and that of the salvage group. A MESS value of 4 was 100% sensitive, a value of 7 was 100% specific, and a value of 7 or more was 100% predictive of amputation. They concluded that the MESS system was an objective and somewhat useful guide to help the treating surgeon better predict the ultimate viability of the mangled lower extremity.

Only one study has applied the MESS system to the mangled upper extremity. Slauterbeck et al[10] retrospectively reviewed the data on 43 patients with mangled upper extremities and found that all 9 with a MESS of 7 or more had undergone amputation, while all 34 with a MESS of less than 7 had undergone successful salvage procedures. They concluded that the MESS system was an accurate predictor of amputation of the severely injured upper extremity and advocated its use as an objective aid to augment the surgeon's clinical experience when faced with the difficult decision of amputation or salvage.

Table 4
Mangled Extremity Severity Scoring System*

Factor	Score
Skeletal / soft-tissue injury	
Low energy (stab, fracture, civilian gunshot wound)	1
Medium energy (open or multiple fracture)	2
High energy (shotgun or military gunshot wound, crush)	3
Very high energy (above plus gross contamination)	4
Limb ischemia	
Pulse reduced or absent but perfusion normal	1†
Pulseless, diminished capillary refill	2†
Patient is cool, paralyzed, insensate, numb	3†
Shock	
Systolic blood pressure always >90 mm Hg	0
Systolic blood pressure transiently <90 mm Hg	1
Systolic blood pressure persistently <90 mm Hg	2
Age, yr	
<30	0
30-50	1
>50	2

*Adapted with permission from Johansen K, Daines M, Howey T, et al: Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma* 1990;30:568-573.
†Double value if duration of ischemia exceeds 6 hr.

Limb Salvage Index

In 1991, Russell et al[8] proposed the Limb Salvage Index (LSI), which was based on a retrospective review of 70 lower-extremity injuries. This index quantifies the likelihood of salvage according to the duration of ischemia and the presence and severity of injury to six types of tissue: artery, bone, muscle, skin, nerve, and deep vein (Table 5). All 51 patients whose limbs were salvaged had an LSI of less than 6, while all 19 who underwent amputation had an LSI of 6 or greater. There was complete disruption of the sciatic, tibial, or peroneal nerve in 95% of amputated limbs. The authors concluded that the LSI was a valuable tool in the evaluation of the patient with a severely traumatized lower extremity.

Bonanni et al[13] applied the LSI retrospectively and concluded that

Table 5
Limb Salvage Index System*

Factor	Score
Arterial injury	
Contusion, intimal tear, partial laceration	0
Occlusion of two or more shank vessels, no pedal pulses	1
Occlusion of femoral, popliteal, or three shank vessels	2
Nerve injury	
Contusion, stretch, minimal clean laceration	0
Partial transection or avulsion of sciatic nerve	1
Complete transection or avulsion of sciatic nerve	2
Bone injury	
Closed fracture or open fracture with minimal comminution	0
Open fracture with comminution or large displacement	1
Bone loss >3 cm; type III-B or III-C fracture	2
Skin injury	
Clean laceration, primary repair, first-degree burn	0
Contamination, avulsion requiring split-thickness skin graft or flap	1
Muscle injury	
Laceration involving single compartment or tendon	0
Laceration or avulsion of two or more tendons	1
Deep vein injury	
Contusion, partial laceration, or avulsion	0
Complete laceration, avulsion, or thrombosis	1
Warm ischemia time, hr	
<6	0
6-9	1
9-12	2
12-15	3
>15	4

*Adapted with permission from Russell WL, Sailors DM, Whittle TB, et al: Limb salvage versus traumatic amputation: A decision based on a seven-part predictive index. *Ann Surg* 1991;213:473-481.

it had a sensitivity of 61% and a specificity of 43%. They contended that the LSI was very detailed, that extensive operative evaluation was required for accurate application, and that accurate scoring in the skin category required that the definitive treatment and its outcome be known. They concluded that the LSI could not be reliably used in the acute decision-making process.

NISSSA Scoring System

In 1994, McNamara et al[9] introduced the NISSSA scoring system —NISSSA being an acronym for the factors nerve injury, ischemia, soft-tissue contamination, skeletal injury, shock, and age (Table 6). This system is a modification of the MESS system, in which the skeletal and soft-tissue components have been separated and a score for nerve injury has been added. In a retrospective review of the data on 24 patients, the authors concluded that although both the MESS and NISSSA systems were highly accurate in predicting amputation, the NISSSA system was more sensitive and specific.

The NISSSA system has the same problems as the MESS system, with the addition of greater complexity in calculating the score due to the addition of a greater number of variables. No other published clinical series has validated the NISSSA system.

Evaluating the Classification Systems

It is important to note that, with the exception of the small prospective series in which the MESS system was validated,[14] all of the published studies assessing the various classification systems have been retrospective investigations. In each, the classification system was applied retrospectively to patients with known outcomes, rather than prospectively to patients with unknown outcomes. The limitations of the retrospective experimental design, as well as the need for more prospective investigations assessing these classification systems, will be discussed later in this review.

It is also important to note that, throughout the clinical literature, “salvage” has been defined as preservation of a viable lower extremity, without regard to limb function. The only studies mentioning “functional failure” are those of Russell et al[8] (who proposed the LSI) and Bonanni et al.[13] Russell et al defined functional failure on the basis of there being a non-weight-bearing extremity without sensory or motor function, while Bonanni et al defined it as the inability to perform any of the following: walking a minimum of 150 feet independently, climbing 12

Table 6
NISSSA Scoring System*

Factor	Score
Nerve injury	
Sensate	0
Loss of dorsal	1
Partial plantar	2
Complete plantar	3
Ischemia	
None	0
Mild	1†
Moderate	2†
Severe	3†
Soft-tissue injury / contamination	
Low	0
Medium	1
High	2
Severe	3
Skeletal injury	
Low energy	0
Medium energy	1
High energy	2
Very high energy	3
Blood pressure	
Normotensive	0
Transient hypotension	1
Persistent hypotension	2
Age, yr	
<30	0
30-50	1
>50	2

*Adapted with permission from 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.
†Double value if duration of ischemia exceeds 6 hr.

stairs, or independently transferring from a bed, a chair, and a bath. Use of this strict definition of failure is likely responsible for the low specificity and sensitivity of all the scoring systems reported by Bonanni et al.

Outcome and Cost of Treatment

The decision to amputate a mangled limb is rarely based on a life-threatening medical emergency and, in today's health-care environment, the surgeon must give strong consideration to the functional outcome and the cost of limb-salvage attempts as compared with amputation. Few published studies, however, have directly compared the functional outcome and the hospital cost of early amputation and limb salvage in the lower extremity.[14,16-18]

Lange et al[4] reviewed the data on 23 patients, 5 who underwent primary amputation and 9 each who underwent delayed amputation and limb salvage. The average number of operations in the primary amputation group was three, compared with six and seven in the delayed amputation and limb salvage groups, respectively. Although none of the patients had a normally functioning limb, no patient in the primary amputation group had significant functional problems, compared with 50% of those in the limb salvage and delayed amputation groups.

Bondurant et al[16] reviewed the data on 43 patients with grade III open tibial fractures that ultimately required amputation, categorizing them into primary amputation (less than 24 hours after injury) and delayed amputation (24 hours or more after injury) groups. The 14 patients in the primary amputation group underwent an average of 1.6 surgical procedures on the involved extremity, spent 22 days in the hospital, and incurred $29,000 in hospital costs. The 29 patients in the delayed amputation group underwent an average of 7 surgical procedures, spent 53 days in the hospital, and incurred $53,000 in hospital costs. None of the patients in the primary amputation group died, compared with 21% of those in the delayed amputation group. Furthermore, 83% of patients in the delayed amputation group required additional surgery on the residual limb. The authors concluded that when amputation is inevitable, performing surgery early enhances patient survival, reduces pain and disability, and shortens hospitalization.

Fairhurst[17] retrospectively compared the functional outcome of patients who sustained traumatic below-knee amputations with that in patients who underwent limb salvage of grade III open tibial fractures. Twenty-four patients, 12 in each group, were examined a minimum of 1 year after completion of treatment. Salvage had been attempted in 8 of the patients who ultimately required amputation; 6 of these 8 wished they had had earlier amputations. All patients in the early amputation group returned to work within 6 months of injury, while those who underwent late amputation and salvage returned to work an average of 36 and 18 months after injury, respectively. Early amputees had significantly better functional scores and more satisfaction with their quality of life than did patients with delayed amputations or salvaged limbs. The authors concluded that, if salvage attempts result in only slow progress, early secondary amputation should be considered a treatment option.

Georgiadis et al[18] retrospectively assessed the functional outcome of patients who sustained grade III-B and grade III-C open tibial fractures and underwent either limb salvage with a microvascular free flap or early transtibial amputation. Limb salvage was successful in 16 of 20 patients followed up an average of 35 months. The 18 patients treated with early amputation were followed up an average of 44 months. The patients with successful limb salvage had more complications, underwent more operative procedures, spent more days in the hospital, and incurred higher adjusted hospital charges than did those who underwent early transtibial amputation. Only 3 patients who underwent limb salvage returned to full-time work, and 12 considered themselves too disabled for any kind of employment. In contrast, 9 patients who underwent early amputation were working full-time, and only 4 considered themselves too disabled for employment. A quality-of-life evaluation tool, the General Well-Being Schedule, revealed that significantly more patients in the limb salvage group considered themselves severely disabled and had problems with the performance of occupational and recreational activities. Both study groups, however, had three to ten times more difficulty in all areas when compared with a healthy reference population. These results underscore the tremendous impact of these injuries on all aspects of a patient's life, regardless of the treatment chosen.

Livingston et al[19] followed up 42 patients a mean of 25 months after traumatic lower limb amputations to evaluate residual disability and identify factors associated with a good recovery. Half of the patients had problems with their prostheses, and only 50% had returned to work. No patient with a transfemoral amputation and only 1 patient with a work-related injury returned to work. Despite the seemingly poor functional results, 88% were satisfied with their situation and could perform all activities of daily living.

Smith et al[20] followed up 24 patients with isolated posttraumatic transtibial amputations for at least 4 years. In the first 3 years, the mean number of prostheses per patient was 3.4, with an average total prosthetic cost of $10,829. When the follow-up was extended to 5 years, the mean number of prostheses per patient was 4.4, with an average total cost of $13,945. All patients had mastered the skills to function without ambulatory aids other than their prostheses, but the time from amputation to plateau of walking ability averaged 1.5 years. Age-matched SF-36 Health Status Profile scores were significantly lower than normal in the categories of physical function and role limitations. The authors concluded that new transtibial amputees should be informed that recovery can take longer than 1 year and that prosthetic fitting is a costly process. Furthermore, they concluded that the transtibial amputee should be counseled that he or she will attain a different level of physical function than was achieved before the amputation.

Williams[21] reported the lifetime costs of Ilizarov reconstruction versus amputation in a small group of patients with grade III-B tibial fractures. The average hospital cost for reconstruction was $59,214; that for amputation was $30,148. Including the projected lifetime average cost for prosthetic limbs and supplies, however, increased the cost for the amputation group to $151,000. (The average cost of prostheses cited in this study was nearly double that reported elsewhere.) The author concluded that Ilizarov reconstruction is a cost-effective alternative to amputation. This study is currently the only published report addressing lifetime prosthetic costs.

At our institution, the mean one-time and estimated 30-year prosthetic costs are $2,196 and $21,960, respectively, for transradial amputation; $4,218 and $42,180 for transtibial amputation; and $5,695 and $56,850 for transfemoral amputation. The 30-year cost is calculated on the assumptions that prosthetic prices remain constant and the patient requires two prostheses in the first 2 years and a new prosthesis every 5 years thereafter.

Recommendations

When treating a patient with a mangled limb, it is highly desirable to obtain and maintain in the medical record photographs of the limb at each stage of the treatment process. These photographs provide invaluable documentation of the extent of injury to the limb as well as a visual record of the amount of progress toward (or away from) a functional, salvaged extremity. If amputation of a mangled limb is to be undertaken, a second opinion from a qualified orthopaedic, general, or vascular surgeon should be requested whenever possible. The presence of a written, concurring second opinion in the medical record may save the surgeon from legal involvement in some situations.

All of the scoring systems for mangled extremities represent attempts to clearly define, at the time of initial evaluation, whether a limb will ultimately be nonfunctional. Although one study reported favorable results with use of the MESS system in mangled upper extremities, none of the current classification systems was specifically designed for use in the upper extremity. We recommend that mangled upper extremities be treated on a case-by-case basis and that the surgeon's clinical judgment and technical skill be the primary guides in choosing limb salvage or amputation. We also recommend, however, that the MESS be calculated to provide guidance and information for the individual surgeon on the success rate for attempted salvage in his or her clinical practice.

In the case of a mangled lower extremity, the surgeon should recognize that there are significant differences between injuries above and below the knee. The functional outcome after a transfemoral amputation is poorer than that after a transtibial amputation. Reconstruction of vascular injuries is frequently easier above the knee than below; however, the outcome after nerve repair above the knee in adults is generally poor. The thicker soft-tissue envelope often makes reconstruction of both bone and soft tissues easier above the knee than below. Thus, unless the sciatic nerve is disrupted, more consideration for limb salvage should be given an injury in the thigh than a similar injury in the leg.

Most authors agree that the mangled adult limb with complete and irreparable loss of sciatic or posterior tibial nerve function should undergo amputation, even if vascularity can be restored. A strong correlation of functional outcome with neurologic injury in all the reported series supports the contention that neurologic function is a good predictor of overall function and outcome. In general, we concur with this conclusion, although it is sometimes clinically difficult to determine initially whether a neurologic deficit is a result of vascular compromise or direct neural trauma.

The current classification systems all have shortcomings, and none has been validated in studies involving large numbers of patients. Retrospective analyses of these systems, using small numbers of patients and multiple variables, are potentially subject to error and must be interpreted cautiously. We expect that the current classification systems will be subjected to prospective, multi-institutional evaluation to better determine their reliability. At present, however, there is no predictive scale that has been adequately validated so that it can be used with confidence to determine whether to amputate or attempt to salvage a mangled lower extremity. We therefore recommend the use of these scoring systems (the MESS system is our preference) as guides to the treatment of mangled lower extremities, but not as substitutes for the treating physician's clinical judgment and experience.

We agree with the recommendations of Roessler et al[12] and Bonanni et al[13] that efforts must be directed toward establishing postoperative guidelines that will assist in the treatment of these injuries. Moreover, as suggested by Georgiadis et al,[18] more comprehensive and critical assessments of the functional outcome, cost, and psychological and social function of patients with salvaged extremities are needed. We believe it reasonable to consider an initial salvage attempt, observation, and subsequent early secondary amputation as a valid treatment option for limbs that do not clearly meet the criteria for primary amputation. The potential for morbidity in this approach lies in prolonged, unsuccessful salvage attempts. More accurate guidelines are needed to prevent delayed amputations, salvage of insensate limbs, and functional failures.

Our current approach to the mangled lower extremity is to calculate a MESS for each patient. Adults with complete and irreparable sciatic or posterior tibial nerve deficits are treated with primary amputation, as are patients with massive amounts of nonviable soft tissue, unreconstructible bone or arterial deformities, and / or loss of the plantar skin and soft tissues. Most other patients are treated with initial attempts at limb salvage. We are careful, however, to discuss with the patient and his or her family the distinct possibility that early secondary amputation will be necessary in the first few postoperative days.

We perform early secondary amputation on those limbs that are considered to be unsalvageable without significant loss of function. Although it is important to allow the patient to participate in the decision for secondary amputation, the surgeon must not allow the patient's enthusiasm for limb salvage to override his own clinical judgment that a functionless limb would be the result.

Summary

The attitude that amputation of a mangled limb represents a therapeutic failure can lead to costly, highly morbid, demoralizing, and sometimes lethal attempts at reconstruction of functionless extremities. The extent of injury to soft-tissue and neurologic structures is highly predictive of the survival and ultimate function of a mangled extremity. The criteria for salvage of the upper extremity are necessarily different from those for salvage of the lower extremity because of the better functional results of salvage and the poorer functional prognosis after amputation in the upper extremity.

All of the scoring systems for mangled extremities represent attempts to clearly identify, at the time of initial evaluation, which limbs will ultimately be nonfunctional. Each system has its limitations. Almost all require information not readily available at the time of initial evaluation, and none was designed for application in the upper extremity or in the postoperative period. Furthermore, validation data have largely been obtained in small, retrospective studies. Therefore, at present, there is no predictive scale that can be used with confidence to determine whether to amputate or attempt to salvage a mangled lower extremity. Efforts should be directed at establishing postoperative guidelines that will assist in early identification of salvaged limbs with poor functional potential that may be best treated with secondary amputation.

Although the hospital cost for primary amputation is far less than that for limb salvage, the lifetime cost of prosthetic devices and their maintenance may offset the differential. More comprehensive and critical comparative assessments of the functional outcome, cost, and psychosocial function of patients with amputated and salvaged extremities are needed.

Upper-extremity injuries should be considered on a case-by-case basis, and the use of scoring systems should not supplant the surgeon's clinical judgment. In the case of a mangled lower limb, adults with complete and irreparable loss of sciatic or posterior tibial nerve function should undergo amputation, even if vascularity can be restored. Until more prospective validation is available, scoring systems should be used only as guides to supplement the surgeon's clinical judgment and experience. It is reasonable to consider an initial attempt at salvage, observation, and subsequent early secondary amputation, if necessary, in limbs that do not obviously meet the criteria for immediate amputation. Prolonged, unsuccessful salvage attempts, salvage of insensate limbs, and functional failures should be avoided.

A complex interplay of issues must be grappled with in making the difficult decision whether to amputate or attempt to salvage a mangled limb. Which of these issues are most important and the relative importance of each have not yet been fully determined. This critical decision-making process remains an art, not a science.

References

1. Peltier LF (ed): *Fractures: A History and Iconography of Their Treatment*. San Francisco: Norman Publishing, 1990, pp 94-95.
2. Kirk NT: Amputations. *Clin Orthop* 1989;243:3-16.
3. Hansen ST Jr: The type-IIIC tibial fracture: Salvage or amputation [editorial]. *J Bone Joint Surg Am* 1987;69:799-800.
4. Lange RH, Bach AW, Hansen ST Jr, et al: Open tibial fractures with associated vascular injuries: Prognosis for limb salvage. *J Trauma* 1985;25:203-208.
5. 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.
6. 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.
7. Johansen K, Daines M, Howey T, et al: Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma* 1990;30:568-573.
8. Russell WL, Sailors DM, Whittle TB, et al: Limb salvage versus traumatic amputation: A decision based on a seven-part predictive index. *Ann Surg* 1991;213:473-481.
9. 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.
10. Slauterbeck JR, Britton C, Moneim MS, et al: Mangled Extremity Severity Score: An accurate guide to treatment of the severely injured upper extremity. *J Orthop Trauma* 1994;8:282-285.
11. Rosenthal RE: The mangled extremity syndrome (MES): A severity grading system for multi-system injury of the extremity [letter]. *J Trauma* 1986; 26:579.
12. Roessler MS, Wisner DH, Holcroft JW: The mangled extremity: When to amputate? *Arch Surg* 1991;126:1243-1249.
13. Bonanni F, Rhodes M, Lucke JF: The futility of predictive scoring of mangled lower extremities. *J Trauma* 1993;34:99-104.
14. Helfet DL, Howey T, Sanders R, et al: Limb salvage versus amputation: Preliminary results of the Mangled Extremity Severity Score. *Clin Orthop* 1990;256:80-86.
15. Robertson PA: Prediction of amputation after severe lower limb trauma. *J Bone Joint Surg Br* 1991;73:816-818.
16. Bondurant FJ, Cotler HB, Buckle R, et al: The medical and economic impact of severely injured lower extremities. *J Trauma* 1988;28:1270-1273.
17. Fairhurst MJ: The function of below-knee amputee versus the patient with salvaged grade III tibial fracture. *Clin Orthop* 1994;301:227-232.
18. Georgiadis GM, Behrens FF, Joyce MJ, et al: Open tibial fractures with severe soft-tissue loss: Limb salvage compared with below-the-knee amputation. *J Bone Joint Surg Am* 1993;75: 1431-1441.
19. Livingston DH, Keenan D, Kim D, et al: Extent of disability following traumatic extremity amputation. *J Trauma* 1994;37:495-499.
20. Smith DG, Horn P, Malchow D, et al: Prosthetic history, prosthetic charges, and functional outcome of the isolated, traumatic below-knee amputee. *J Trauma* 1995;38:44-47.
21. Williams MO: Long-term cost comparison of major limb salvage using the Ilizarov method versus amputation. *Clin Orthop* 1994;301:156-158.